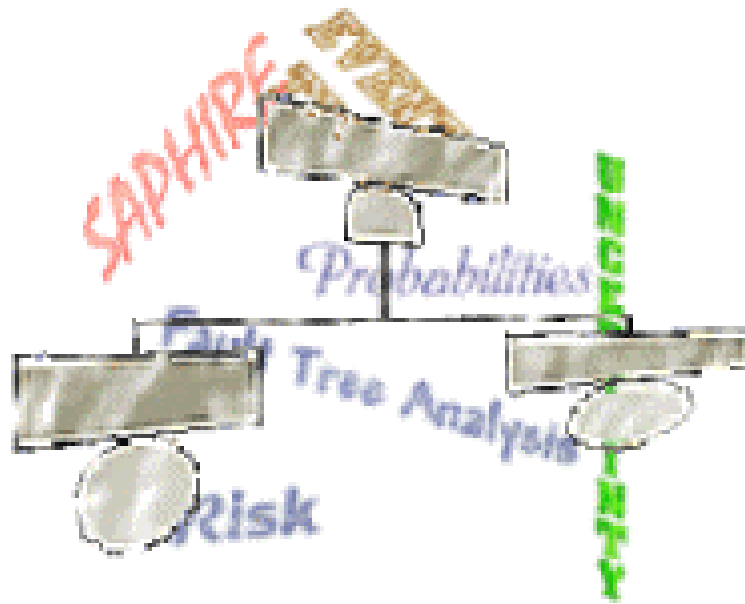


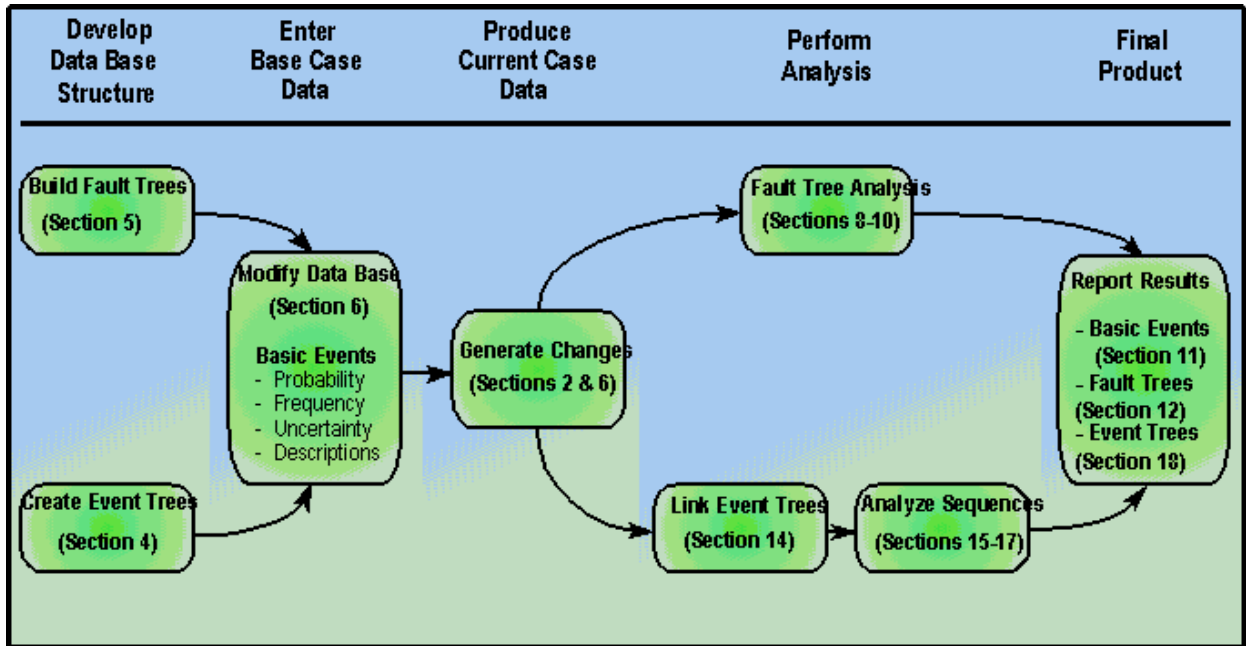
Systems Analysis Programs for Hands-On Integrated Reliability Evaluations (SAPHIRE)

"The Basics" Manual

SAPHIRE Users Group



SAPHIRE - "The Big Picture"



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Note that the contents of this manual may be superseded by the information contained within the electronic help file that is supplied with SAPHIRE for Windows. Please refer to the built-in SAPHIRE help if specific questions arise on a particular topic. Questions or comments concerning this document should be sent to:

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1. INTRODUCTION

Section 1 contains an introduction to the SAPHIRE [Basics course material](#), an [overview of PRA](#), and important definitions and concepts. Also included in this section is an overview of the SAPHIRE [code capabilities](#).

Learning Objectives

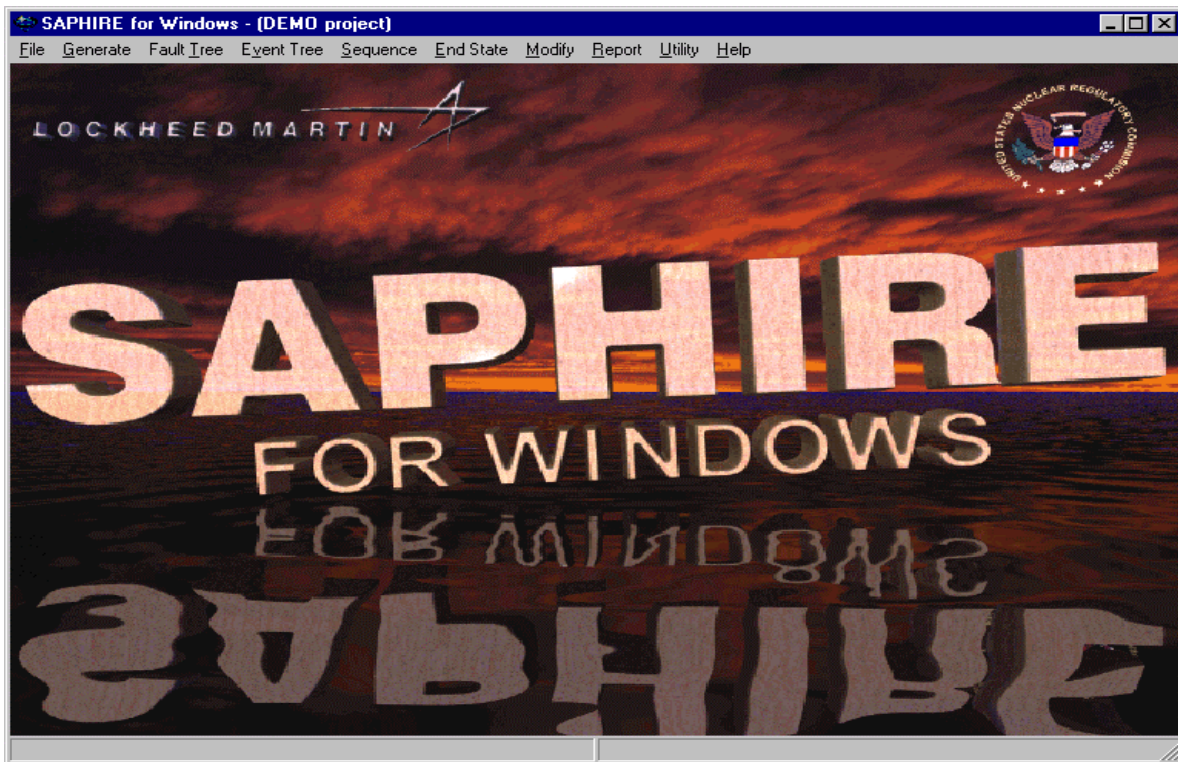
- ◆ Install SAPHIRE on an IBM compatible computer.
- ◆ With SAPHIRE loaded on an IBM compatible computer, start the program.
- ◆ Define PRA terminology important to this class.
- ◆ Describe the major steps in the PRA process

1.1 Overview of SAPHIRE Basics Course Material

The SAPHIRE Basics course material is intended to both (1) provide guidance for learning SAPHIRE during the Basics class and (2) become a stand-alone reference document after finishing the class. Thus, the format for the class material is a combination of the traditional [overhead-type] of presentation information with a structured, reference-type document.

The course material is divided into two general categories. [Menu-centered] topics are first presented and are then followed by [task-centered] topics.

- ◆ The term [menu-centered] implies that the SAPHIRE menu options will be discussed. For example, one menu-centered topic will be to learn how to build graphical event trees. Sections 2 through 6 contain menu-centered information.
- ◆ The term [task-centered] implies that performing certain tasks using the SAPHIRE code will be discussed. For example, one task-centered topic will be to learn how to obtain event tree sequence cut sets. Sections 7 through 21 contain task-centered information.



- ◆ SAPHIRE screen displays will be shown as they appear on your video display (as shown above).
- ◆ Square bullets (□) will be used to discuss topics relevant to an SAPHIRE screen display.
- ◆ When discussing a particular sequence of menu options, the nomenclature

MAIN Menu → Submenu Option

will be used to indicate the main SAPHIRE menu option and any successive submenu options.

1.2 SAPHIRE - What Is It and What Can It Do?

- ◆ SAPHIRE is an integrated PRA software tool that give the user the ability to create and analyze **fault trees** and **event trees** using a personal computer.
- ◆ IRRAS was originally released in 1987 (version 1.0). Other versions of IRRAS include 2.0, 2.5, and 4.0. Additions and improvements have been added to each version of the code.
- ◆ The latest version of the SAPHIRE code is 6.0. The material contained in the class notes is current and includes changes made from IRRAS version 5.0.

- ◆ SAPHIRE contains several features:
 - ◇ PC-based fault tree and event tree graphical and text editors
 - ◇ Cut set generation and quantification
 - ◇ Importance measures and uncertainty modules
 - ◇ Relational database with cross-referencing features
 - ◇ External events analysis (e.g., seismic, location transformation)
 - ◇ Rule-based recovery and end-state analysis

- ◆ Version 5.0 was the first IRRAS release that contained 32-bit compiled code (a 16-bit code is still available). Features of the 32-bit code include:
 - ◇ Reduced analysis time due to improved code execution.
 - ◇ Use of available extended memory (i.e., memory above the normal 640K of DOS memory).
 - ◇ Ability to solve larger logic models due to improved memory handling.
 - ◇ The code occupies less disk space since individual modules are compiled into a single module.
 - ◇ Only 386, 486, Pentium, or higher DOS compatible computers can run the 32-bit version of SAPHIRE.

- ◆ Version 6.0 is the first SAPHIRE release for Windows 95 and Windows NT.

- ◆ The minimal hardware requirements are:
 - ◇ 386 or higher Windows 95/NT compatible computer with 8 (Windows 95)/20 (Windows NT) Megs available memory (RAM).
 - ◇ 6 Megs of memory on the hard disk for program installation. The required hard disk memory for each database varies depending on the size and complexity of the database.
 - ◇ 16 color EGA/VGA monitor/video card and a keyboard and mouse (or other pointing device).
 - ◇ Windows 95 or Windows NT.
 - ◇ A math coprocessor is optional but is recommended.

1.3 The Class Workbook

- ◆ The workshop problems for the SAPHIRE class are contained in a separate handout, referred to as the "workbook" or "workshop manual."

- ◆ The workbook allows the SAPHIRE Basics class to be tailored to specific audiences. This "tailored-problem" format gives the freedom to present specific topics or problems centered around the expected needs of the students.
- ◆ The workbook follows the same format as the course material, and together provide an integrated reference package for the SAPHIRE code.

1.4 Overview of PRA

- ◆ Probabilistic risk assessment (PRA) is a method to:

Identify, characterize, quantify probabilistically, and evaluate *hazards*

- ◆ The process of measuring **risk** (i.e., PRA) asks:
 - ◇ What can go wrong?
 - ◇ How likely is it?
 - ◇ What are the consequences?
- ◆ The **NUREG-1150** type PRA process consists of three major levels.

1.5 Definitions

- ◆ **Hazards could include**
 - ◇ Ionizing radiation (e.g., a nuclear power plant radiation release)
 - ◇ Electrical hazard (e.g., electrical shock)
 - ◇ Thermal hazard (e.g., thermal blast effects from an explosion)
 - ◇ Chemical hazard (e.g., a release of toxic chemicals)

- ## ◆ Risk

The potential of loss or damage resulting from exposure to a **hazard**.

◆ Safety

Represents an acceptable level of **risk** relative to the benefits derived from the **hazards**-causing activity.

◆ Probability

The two common interpretations of *probability* are:

Frequentist (*the relative frequency or empirical approach*) ▮ The probability of event A is given by:

$$P(A) = \lim_{n \rightarrow \infty} (X / n)$$

where X is the number of times event A occurred out of n number of repeated trials. For a fixed n , the value of $P(A)$ is the *relative frequency* of occurrence of event A. Consequently, increasing n will improve the estimate of $P(A)$.

Subjective (*the degree of belief approach*) ▮ The probability $P(A)$ is the measure of uncertainty or degree of belief one has of event A. For example, the knowledge of symmetry for a particular coin may lead an analyst to postulate that the probability of tossing a head on a toss is 0.5. The subjective method requires that probability be assigned in a consistent manner.

◆ Reliability

The **probability** that a system will perform satisfactorily (i.e., does not fail) for a designated period of time (or number of cycles) and under specified operating conditions. The **Unreliability** is the complement of the reliability, that is, the probability that the system *does fail* within a designated period of time and under specified operating conditions.

◆ Availability

The instantaneous availability is the **probability** that a system will perform satisfactorily at a designated point in time when used under specified operating conditions. The evaluation of system availability includes operating time, time to test, active repair time, administrative time, and logistics time. The **Unavailability** is the complement of the availability.

◆ **Accident Sequence**

The combination of an initiating event with system failures and successes (defined by an event tree) which results in a definable outcome. For a nuclear power plant PRA, the outcome is generally core damage.

◆ **Dominant Contributors**

Failures which are quantitatively the largest contributors (i.e., [dominant]) to the likelihood of the defined event (e.g., accident sequence, system failure).

◆ **Minimal Cut Set**

A minimum combination of failures needed to result in the occurrence of the event of interest (e.g., accident sequence, system failure).

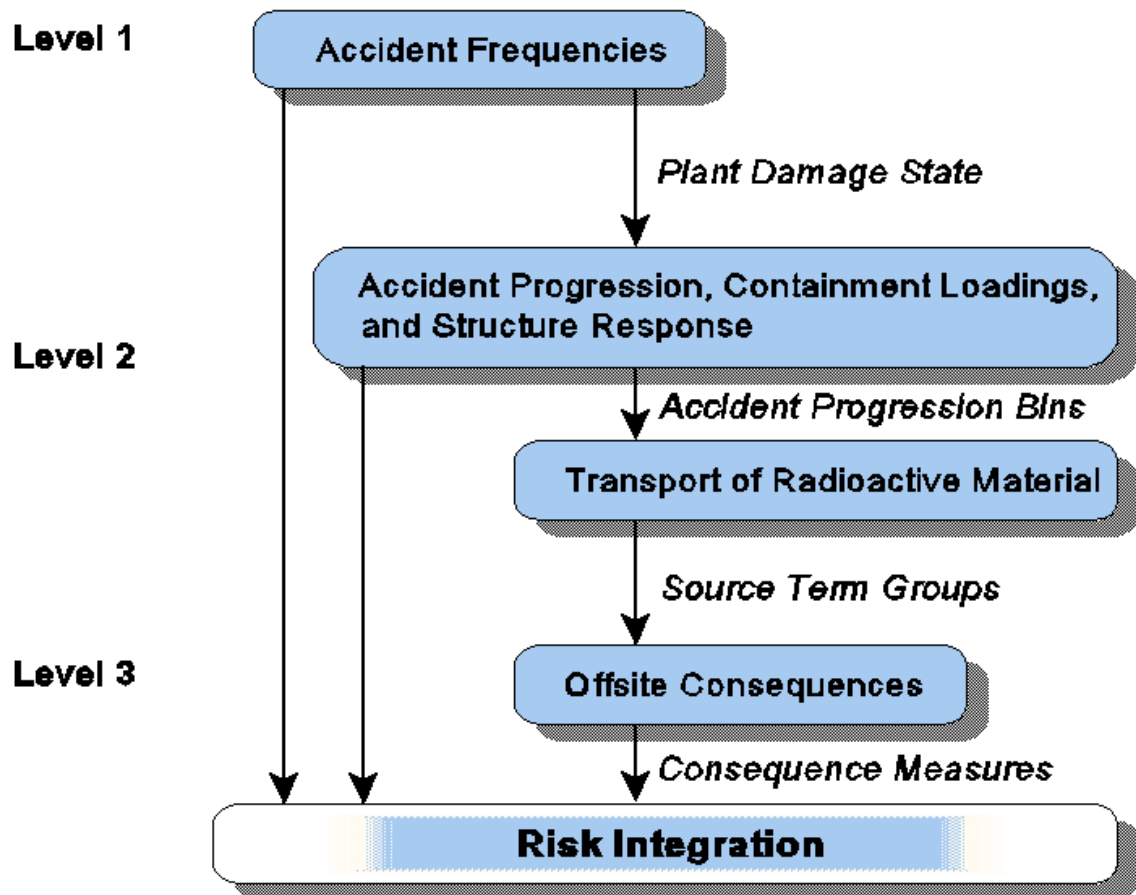
◆ **Consequence**

A measure of the degree of damage or loss experienced given a particular **accident sequence**. For a nuclear power plant PRA, an accident sequence consequence is generally the anticipated offsite radiation dose to the population surrounding the plant.

◆ **Fault Tree Linking**

A technique whereby the fault tree logic is combined with the event tree logic (i.e., successes and failures) resulting in a logic expression for each sequence in the event tree.

1.6 Major Steps The "NUREG-1150 Type" PRA Process



- ◆ The output of the Level 1 PRA is the core damage frequency and includes:
 - ◇ Identification of **accident sequences** and their frequencies.
 - ◇ Identification of **dominant contributors** to core damage.
 - ◇ Classification of accident sequences into Plant Damage States.
- ◆ **Event tree** and **fault tree** analysis are most commonly used in Level 1 PRA.

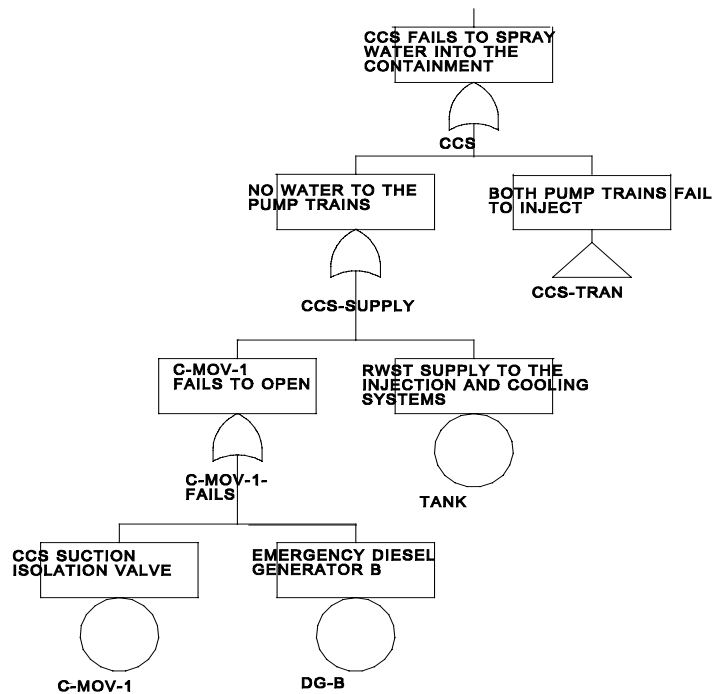
Event Trees

Loss of Offsite Power Initiating Event	Emergency Cooling	Containment Cooling	SEQ #	ENDSTATE
LOSP	ECS	CCS		
<pre> graph LR A[Loss of Offsite Power Initiating Event] --> B[Emergency Cooling] B --> C[OK] B --> D[SMALL-RELEASE] B --> E[LARGE-RELEASE] B --> F[Containment Cooling] F --> D F --> E F --> E </pre>			1	OK
			2	SMALL-RELEASE
			3	LARGE-RELEASE

- ◆ Event trees are logical representations of significant plant responses to initiating events.
 - ◇ Each sequence results in either a safe condition (e.g., safe shutdown) or an accident condition (e.g., core damage).
 - ◇ Event trees relate systems and functions to a particular sequence progression.
 - ◇ Event trees provide an end-to-end traceability of accident sequences.
- ◆ Event trees provide a traceable way to perform the following functions:
 - ◇ Identify **accident sequences**.
 - ◇ Identify essential **safety** system functions.
 - ◇ **Quantify** sequence frequencies.

Fault Trees

Containment Cooling Fault Tree



- ◆ Fault trees are logical representations of the credible failures that can cause an undesired event to occur.
 - ◇ The undesired event is stated at the top of the fault tree.
 - ◇ The fault tree gates specify the logical combinations of basic events that lead to the top event.
 - ◇ Fault trees can be used to identify system weaknesses.
 - ◇ Fault trees can help to recognize interrelationships between fault events.
 - ◇ SAPHIRE evaluates the fault tree to find system minimal cut sets and the system failure probability.
- ◆ Fault trees consist of logic gates and basic events as inputs into the logic gates.

Logic Gates

Represent the Boolean operation (e.g., union, intersection) of the input events.

Basic Events

Represent a fault such as a hardware failure, human error, or an adverse condition.

1.7 Accident Sequence Quantification Steps

- ① Link fault models to the event tree sequences.
- ② Evaluate each accident sequence for minimal cut sets.
- ③ Quantify the accident sequence minimal cut sets with event data.
- ④ Add operator recovery actions and common-cause failures (if not already in the fault tree and event tree logic models).
- ⑤ Determine the dominant accident sequences.
- ⑥ Partition the accident sequences into appropriate plant damage state bins.
- ⑦ Perform sensitivity, importance, and uncertainty analysis on the accident sequences.

1.8 Installation of SAPHIRE

- ◆ To install:
 - ◇ Place the installation disk labeled, "SAPHIRE Disk 1," the floppy disk drive.
 - ◇ From the Windows 95 (or NT) Start Bar, click **Run**.
 - ◇ In the **Open** field, type a:\SETUP or **Browse** for the setup file on the floppy disk..
 - ◇ Choose **Ok**.
 - ◇ The Setup program prompts you through the installation process. Follow the instructions on the screen.

- ◆ The installation program will make an installation subdirectory if needed.
- ◇ Any databases (such as the DEMO database) will be contained in a subdirectory in the destination directory (e.g., SAF60\DEMO).
- ◇ The database subdirectory will contain the relational database files.
 - *.IDX files contain data indices.
 - *.BLK files contain variable length data (e.g., cut sets).
 - *.DAT files contain actual data and data pointers.

1.9 SAPHIRE Constants

The SAPHIRE Constants dialogs are used to customize the SAPHIRE code.

- ◆ Four constants dialogs are available.
 - ◇ [General] information
 - ◇ [Cut-Sets] information
 - ◇ Fault tree graphics default values
 - ◇ Event tree graphics default values
- ◆ The constants can be modified by:
 - ① Using the mouse to move to a particular field.
 - ② Change the constant(s) and select the next Define Constants dialog.
 - ③ Click **Save** to save all your "constant" choices for the project that is currently selected.
 - Choose **Global Save** to save your "constant" choices to a central storage file.
 - Choose **Global Load** to load the constants stored in the central storage file.

TIP Once the constants are changed to the desired settings, click the **Global Save** button. Then, when you select another database, you can retrieve the settings by clicking the **Global Load** button. Also, when you start a new database from scratch, the constants stored by the "Global Save" option will be used as the initial defaults.

- ◆ The following constant screens should to be accessed and the appropriate settings made prior to creating a new Project or before clicking the **Global Save** button.

"General" constants screen

The screenshot shows the 'Define Constants' dialog box with the 'General' tab selected. The dialog has a title bar with a question mark and a close button. Inside, there are four tabs: 'General', 'Cut Set', 'Fault Tree', and 'Event Tree'. The 'General' tab contains the following fields and controls:

- User Name:** A text field containing 'Lockheed Martin Idaho Technologies'.
- Analysis type:** A dropdown menu set to 'RANDOM'.
- Display method:** A group box containing three radio buttons: 'Toolbar only' (selected), 'Menu only', and 'Toolbar and Menu'.
- Toolbar buttons:** A group box containing three radio buttons: 'Picture only', 'String only', and 'Picture and String' (selected).
- Toolbar position:** A group box containing three radio buttons: 'Top', 'Left' (selected), 'Bottom', 'Right', and 'Adjustable'.
- Use alternate basic event names:** An unchecked checkbox.
- Model Solution Type:** A text field with a small dropdown arrow, currently blank.
- (Leave blank= show all, N=show normal, A=show):** A note below the Model Solution Type field.
- Global Save:** A button.
- Global Load:** A button.
- Uncertainty values:** A group box containing two text fields: 'Random number seed' (set to '0') and 'Sample size' (set to '1000').
- Uncertainty method:** A group box containing two radio buttons: 'Latin Hybercube' and 'Monte Carlo' (selected).
- Importance Measurement type:** A group box containing three radio buttons: 'Ratios' (selected), 'Difference', and 'Uncertainty'.
- OK:** A button.
- Cancel:** A button.

The general constant screen allows for general use information to be added.

The "Uncertainty Values" option sets the default uncertainty analysis type by selecting either Latin Hypercube or Monte Carlo radio button. Also, the random seed and number of samples can be specified.

The "Importance Measurement Type" option sets the default importance measure to be reported when an importance measure report is outputted.

"Cut Set-attributes" constants screen

The screenshot shows the 'Define Constants' dialog box with the 'Cut Set' tab selected. The dialog has a title bar with a question mark and a close button. Below the title bar are four tabs: 'General', 'Cut Set', 'Fault Tree', and 'Event Tree'. The 'Cut Set' tab is active. The 'Cut Set Generation' section contains several options: 'Cutoff by Probability' is checked with a value of 1.000E-015; 'Cutoff by Event Probability' is unchecked with a value of 1.000E-015; 'Size Truncation' has three radio buttons: 'Zone' (unchecked), 'Size' (unchecked), and 'None' (checked) with a value of 6; 'Solve Sequence with Fault Trees' is checked with a mission time of 2.400E+000; and 'Auto Apply Recovery Rules' is checked. The 'Gather End States By' section has two radio buttons: 'Sequence End State' (checked) and 'Cut Set Partition' (unchecked). The 'Quantification Method' section has three radio buttons: 'Mincut' (checked), 'Rare Event' (unchecked), and 'Min/Max' (unchecked), with a 'Min/Max Passes' field set to 3. The 'Transformations' section has two checkboxes: 'Transform zones' (unchecked) and 'Include random' (unchecked), with a 'Level' field set to 0. At the bottom, there is a checkbox for 'Use Base cut sets for Update' which is unchecked. 'OK' and 'Cancel' buttons are at the bottom right.

Define Constants

General | **Cut Set** | Fault Tree | Event Tree

Cut Set Generation

☒ Cutoff by Probability Value: 1.000E-015

☐ Cutoff by Event Probability Value: 1.000E-015

Size Truncation: ☐ Zone ☐ Size ☒ None Value: 6

☒ Solve Sequence with Fault Trees Mission time: 2.400E+000

☒ Auto Apply Recovery Rules

Gather End States By:

☒ Sequence End State ☐ Cut Set Partition

Quantification Method

☒ Mincut ☐ Rare Event ☐ Min/Max Min/Max Passes: 3

Transformations

☐ Transform zones ☐ Include random Level: 0

Use Base cut sets for Update ☐

OK Cancel

The Cut Set Generation options are used when generating both fault tree and sequence cut sets. The options marked by a check in the box and the value specified will be used when generating either fault tree or event tree cut sets.

TIP Make sure the "solve sequences with fault trees" option is checked in order to tell SAPHIRE to use the fault tree logic when generating accident sequence cut sets. Also, make sure that the "auto apply recovery rules" option is checked in order to tell SAPHIRE to automatically apply recovery rules (if they are defined) to the cut sets after generation.

The "Mission time" field specifies the default mission time. The default mission time is used only for those basic events that have a mission time of zero.

The "Quantification Method" option specifies which analysis method to use when quantifying the cut sets.

"Fault Tree Graphics" constants screen

The screenshot shows a Windows-style dialog box titled "Define Constants" with a blue header bar containing a question mark and a close button. The dialog has four tabs: "General", "Cut Set", "Fault Tree" (which is selected), and "Event Tree". The "Fault Tree" tab contains several sections for defining graphical constants:

- Shape Names:** Two text input fields. The "Gate" field contains the text "GATE" and the "Event" field contains the text "EVENT".
- Shape Attributes:** A "Name Font" button, a "Fill Color" dropdown menu set to "Blue", and an "Outline Color" dropdown menu set to "Maroon".
- Line Attributes:** A "Style" section with three radio buttons: "Solid" (selected), "Dashed", and "Dotted", each followed by a corresponding line style preview. A "Line Color" dropdown menu is set to "Black".
- Text Attributes:** A "Text Font" button, a "Horizontal" section with three radio buttons: "Left", "Center" (selected), and "Right", and a "Vertical" section with three radio buttons: "Base", "Bottom", and "Top" (selected).
- Other:** Three checkboxes: "Show Names" (checked), "Show Text" (checked), and "Show Grid" (unchecked). A "Background" dropdown menu is set to "White".

At the bottom of the dialog are "OK" and "Cancel" buttons.

The fault tree graphic constant screen should be verified prior to creating any fault tree graphics. Check to make sure that the graphical colors that are selected will result in a readable fault tree (e.g., do not select black lines on a black background). The constants shown above are for illustration purposes, change the color/font scheme to your preferences.

"Event Tree Graphics" constants screen

The screenshot shows a Windows-style dialog box titled "Define Constants" with a blue header bar containing a question mark and a close button. Below the header is a tabbed interface with four tabs: "General", "Cut Set", "Fault Tree", and "Event Tree". The "Event Tree" tab is selected. The dialog is divided into three main sections: "Top Attributes", "Text Attributes", and "Other".

Top Attributes:

- "NAME display width" is set to 8 characters, with a "Name Font" button next to it.
- "DESCRIPTION display height" is set to 3 lines, with a "Desc Font" button next to it.
- "Top Background Color" is set to "Gray" via a dropdown menu.

Text Attributes:

- A "Text Font" button is present.
- A "Hide Text" checkbox is unchecked.
- "Horizontal Justification" has three radio buttons: "Left" (unselected), "Center" (selected), and "Right" (unselected).

Other:

- "Background Color" is set to "Blue" via a dropdown menu.
- "Line Color" is set to "Yellow" via a dropdown menu.
- "Tree Leaf Height" is set to 0.
- An "End State Font" button is present.

At the bottom right of the dialog are "OK" and "Cancel" buttons.

The event tree graphic constant screen should be verified prior to creating any event tree graphics. Check to make sure that the graphical colors that are selected will result in a readable event tree (e.g., do not select black lines on a black background). The constants shown above are for illustration purposes, change the color/font scheme to your preferences.

2. DATABASE CONCEPTS

Section 2 presents an overview of the SAPHIRE database structure. Included in this section are discussions of SAPHIRE **projects**, **base case versus current case**, **base case updates**, and **change sets**.

- ◆ Define the two major parts of the SAPHIRE project that store data.
- ◆ Add and select a new project.
- ◆ Explain the Generate Event Data option.
- ◆ State the general concepts for using change sets.

2.1 SAPHIRE Projects

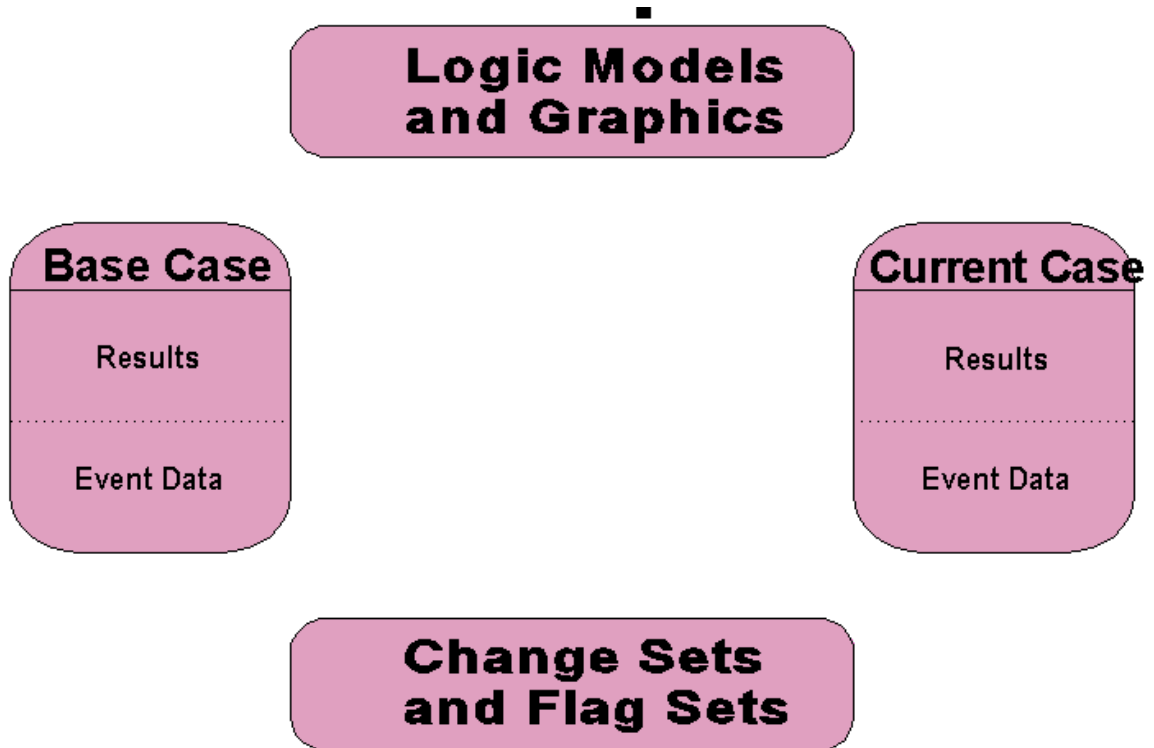
- ◆ In SAPHIRE, the term **project** represents a single, specific data base.
- ◆ When starting a PRA, a project must be created (via the **File → New Project** option).
 - ① Click the backup up one level folder or use the menu bar to select the directory where the new project is to be added.
 - ② Right click the mouse and scroll down to **new → folder**
 - ③ Add the new folder (name) directory for the project.
 - ④ Select the newly created project folder
 - ⑤ In the file name field, type in the project name (up to 24 characters).
 - ⑥ The project can now be modified using (**Modify → Project**).
- ◆ To access a particular project, the project must be selected (via the **File → Open Project** option).
 - ◇ Modifications to a data base (e.g., a new fault tree is developed) are always made to the currently selected project.
 - ◇ For a given project, only one list is kept for all types of information. Thus, within a project, only a single copy of a particular fault tree, event tree, or basic event is ever stored in the data base.
- ◆ Each project is contained within a separate subdirectory in the SAPHIRE directory.

Project (Definition)

A group of fault tree logic and graphics; event trees and sequences; basic events and related data; cut sets; analysis results; and descriptions.

2.2 Base Case Versus Current Case Data

- ◆ Base case and current case are two separate parts of a project data base.
 - ◇ **Base Case** data is stored in the data base files as a [permanent] record
 - ◇ **Current Case** data is used to perform an analysis (e.g., cut set generation and quantification)



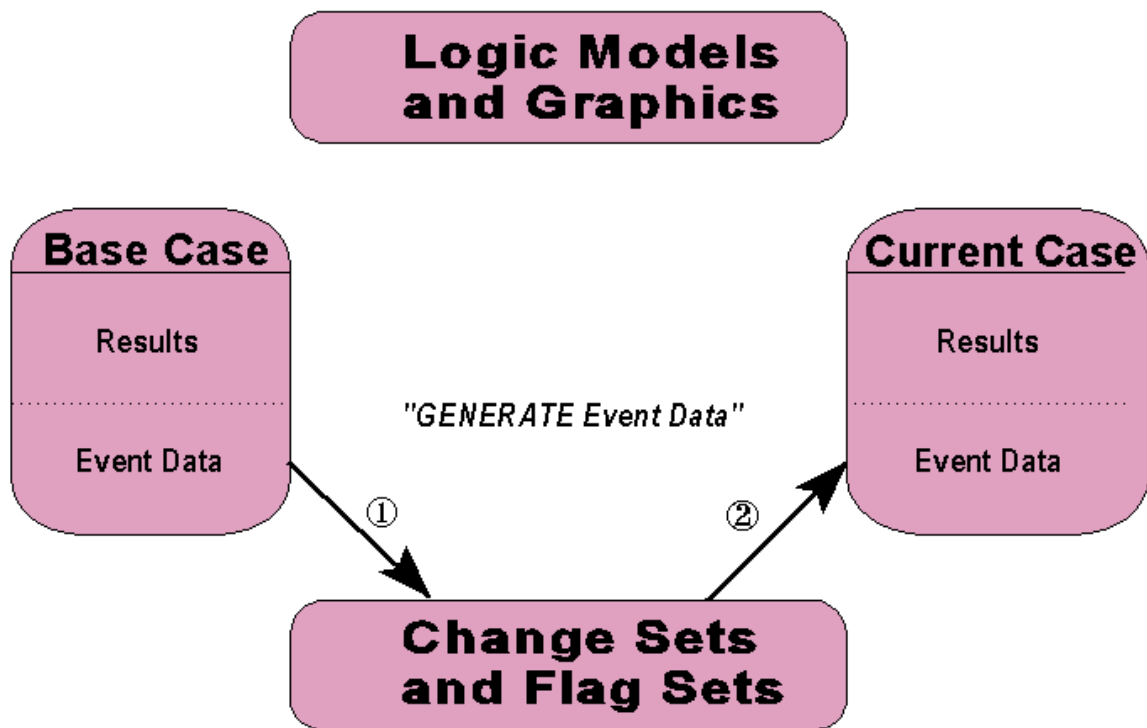
Current Case Is

- ◇ Created (via the **Generate** option) by applying change sets to base case data
 - ◇ Used for sensitivity or event analysis
 - ◇ Not stored in relational database (only the change set and base case data are stored)
- ◆ All SAPHIRE calculations use the data stored in the **current** case.
 - ◆ Current case is sometimes referred to as the Alternate case.
 - ◆ Current case can equal the base case in order to reproduce the original study stored in the base case.

- ◆ Only current case cut sets can be modified with the cut set editor. Changes made to cut sets with the cut set editor are implemented automatically (no cut set update is necessary).

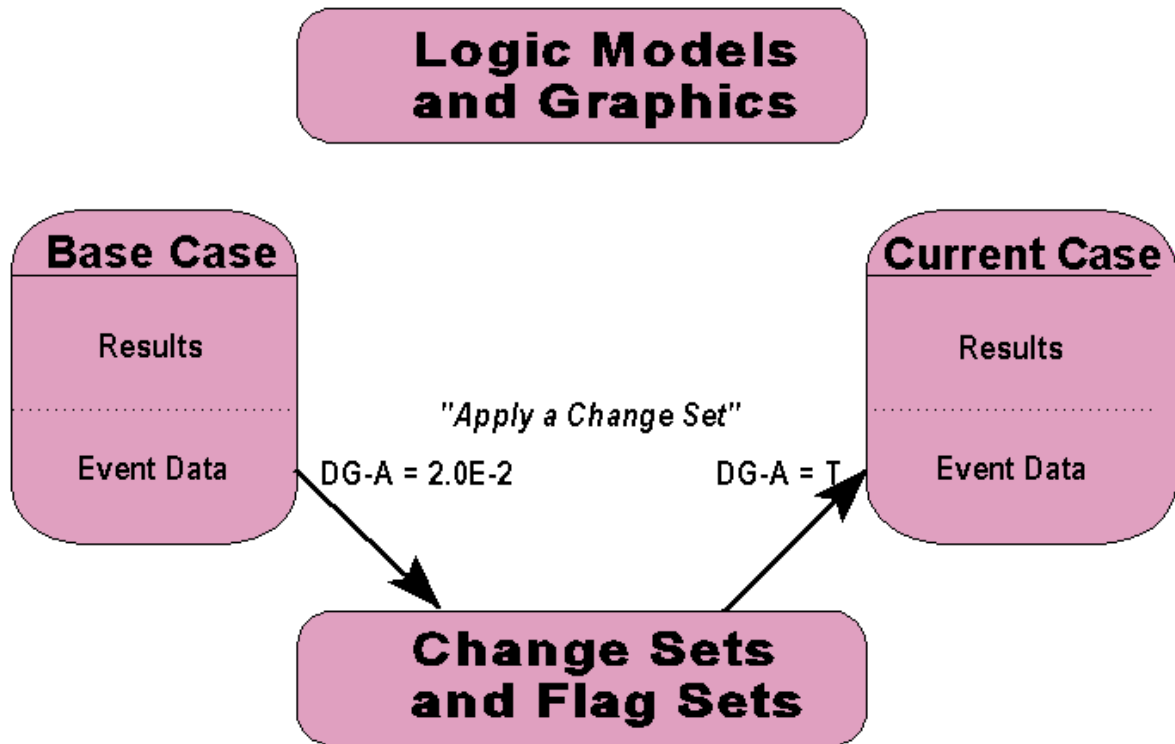
2.3 Generating Event Data

Generate option transfers **base case** data to the **current case** (after making changes specified in any marked change sets). SAPHIRE always uses current case data for analysis. If the base case data is changed and the **Generate** option is *not* performed, the data that is used for the analysis will not reflect the changes.



Change Sets (Definition)

Change Sets are a user-defined set of changes that will be applied to the base case data when event data is transferred to the current case (via the **Generate** option). Multiple change sets can be defined and applied singly or in combination.



2.4 Rules for Creating and Using Change Sets

- ◆ No limit to the number of change sets that can be added to the data base
- ◆ Change set name is limited to 24 characters, the description is limited to 60 characters
- ◆ A change set can contain one **class change** and unlimited individual **probability changes**.
- ◆ Multiple change sets can be used in combination to create different sensitivity studies.

EXAMPLE: Two change sets are developed. The first is named **[A]** and sets all valves to failed. The second is named **[B]** and sets all pumps to failed. The possible scenarios are

Change set(s) that are marked	Sensitivity case
None	Original base case analysis
A	Valves failed
B	Pumps failed
A and B	Both valves and pumps failed

- ◆ The order of "marking" a change set is important. (Change sets are marked by double-clicking the line containing the change set.)
- ◆
 - ◇ The first selected change set will be the first one that is applied
 - ◇ Later changes will overwrite earlier ones if there is any overlap
 - ◇ Within a change set, individual probability changes will overwrite a class change
- ◆ Base case data and changes made to the current case can be viewed by using the **Generate → Report** option.
 - ◇ Unaffected events *(those events not modified by a change set)*
 - ◇ Affected events *(those events which are modified by a change set)*
 - ◇ All events *(the current probability for all events)*

Class Changes

Class changes use a basic event attribute to search for a class of basic events to which the defined change applies

- The search criteria are defined first
- The change to be applied is then defined

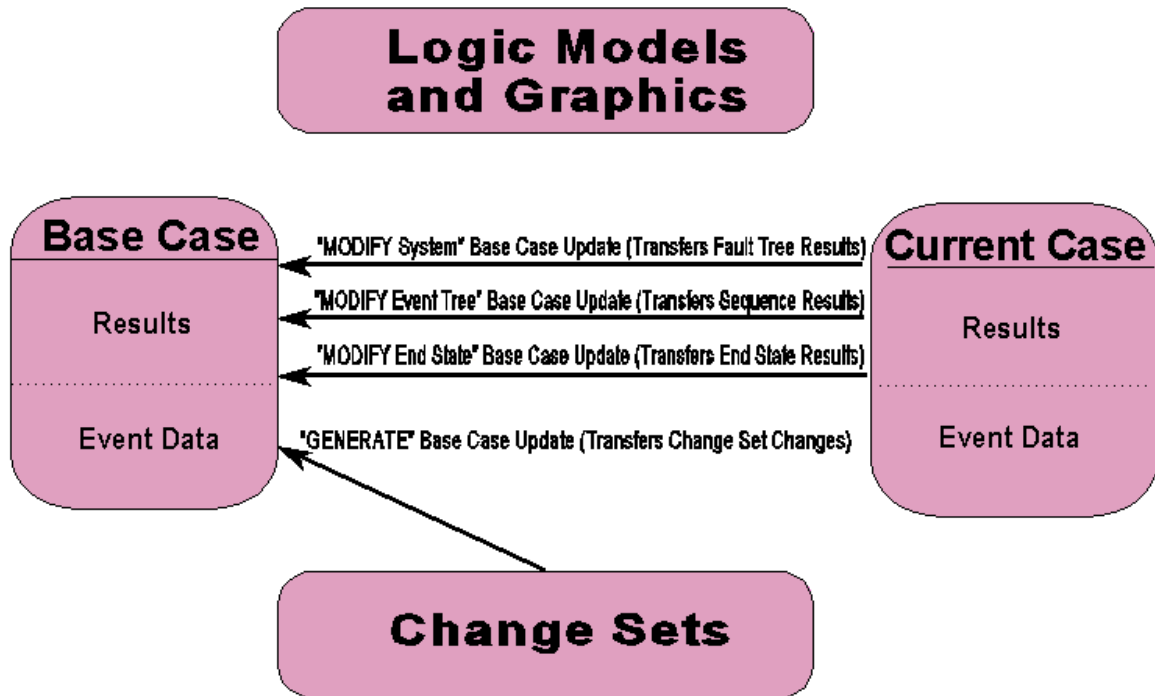
Single (a.k.a. Probability) Changes

Single changes only modify individual, user-identified basic events

- The desired basic event is selected
- The changes to the basic event are then defined

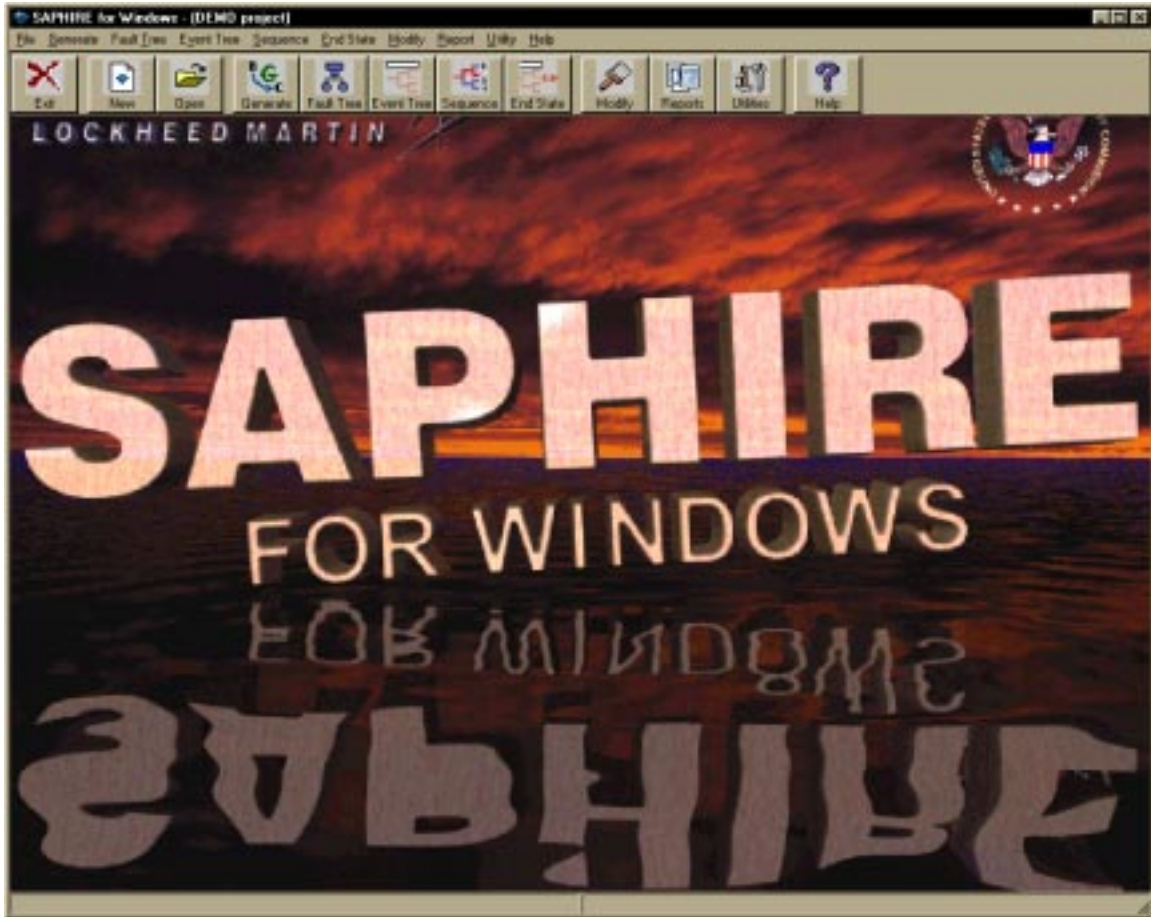
2.5 Base Case Update

- ◆ Base case data and results are changed by **updating** the **base case**. Updating the base case transfers the **current case** data or results into the base case.
- ◇ **Base Case** results are stored in the data base files as a [permanent] record



3. MENU STRUCTURE

Section 3 presents a breakdown of the menu structure of SAPHIRE. The menu structure is shown for the **main menu** and the associated sub-menus. Accompanying each menu item is a description of the function for that menu option.



3.1 The Menu Bar

- ◆ The SAPHIRE menu bar shows the major options. Shown above is the menu bar and the graphical tool bar
- ◆ The currently selected project is shown in the title bar (the DEMO project is shown here).

3.2 File

The **File** drop-down menu contains the Project options and Exit options.

- ◆ **Exit** leaves the SAPHIRE code.
- ◆ **New Project** is used to create a new project.
- ◆ **Open Project** is used to change the current data base. The *Open Project* dialog allows you to select a project for use as the current data base.
- ◆ A list of the most recently used projects are also shown under the file menu.
- ◆ **Close Project** is used to close the current working project.

3.3 Generate

The *Generate* dialog is used to update and modify the current case data. This option allows individual events or a group of events that meet a user-defined search criterion to be modified in the highlighted change set. By pressing the right-hand mouse button while the *Generate* dialog is active, a pop-up menu will appear which allows you to add a change set, modify the name or description of the highlighted change set, or delete the highlighted change set. Double-clicking with the left-hand mouse button marks/unmarks the highlighted change set.

3.4 Fault Tree

The **Fault Tree** option allows you to build, edit and analyze fault tree models. When you select the Fault Tree option the *Fault Tree* dialog appears listing all systems in the current project. A pop-up menu provides various functions, depending on how many, if any, systems are selected. The pop-up menu allows you to add a fault tree and edit its logic either graphically or by logic editor. The pop-up menu is also used to generate, quantify, manipulate, and display fault tree cut sets. This option allows you to view and edit event tree cut sets, to develop and apply cut set manipulation rules, and plot seismic curves.

3.5 Event Tree

The **Event Tree** option is used to add new event trees, access the graphical event tree editor, generate sequence logic, edit top event substitution rules, and edit event tree logic. When you select the Event Tree option the *Event Tree List* dialog appears listing all event trees in the current project.

3.6 Sequence

The **Sequence** option is used to generate, quantify, manipulate, and display event tree sequences. The *Sequences* dialog allows you to view and edit event tree cut sets, to develop and apply cut set manipulation rules, and plot seismic curves. This option also allows generation of sequence logic, editing of top event substitution rules, and editing of event tree graphics (*.ETG) file.

3.7 End State

The **End State** option is used to gather, analyze, and perform uncertainty analysis on end state cut sets (covered in Advanced SAPHIRE course). The *End State List* dialog allows you to report (to the Viewer or printer) end state cut sets gathered and quantified; importance analysis; and uncertainty analysis. This option also allows the end states to be viewed and the cut sets to be edited.

3.8 Modify

The **Modify** option is used to add, delete, edit, or modify information contained in the data base. This option allows you to perform those functions described above to the project, event trees, systems, end states, basic events, attributes, analysis types, gates, histograms, P&IDs, change sets, and flag sets.

3.9 Report

The **Report** option is used to display or print data base information reports. This option allows you to print information for the projects, attributes, basic events, systems, event trees, end states, sequences, gates, histograms, and user information. The project outputs are description, text, and statistics. The event tree outputs are logic, initiating events, and cross-reference information. The system outputs are results, cut sets, logic, importance results, and cross-reference information. The sequence outputs are results, cut sets, logic, and importance results. The end state outputs are results, cut sets, importance results, and cross-reference information. The basic event outputs are information, probability data, uncertainty data, transformation data, and cross-reference information. The attribute outputs are system types, failure modes, location, event type, and train. The histogram outputs are summary (type, name, and description) and probability values. The gate output is cross-reference information. The user information output is the default constants defined in the constants dialog.

3.10 Utility

The **Utility** option is used to archive or recover the data base; change default settings for hardware type, analysis parameters, and graphical output; load or extract files into or from the current project, or load or extract fault tree and event tree graphics.

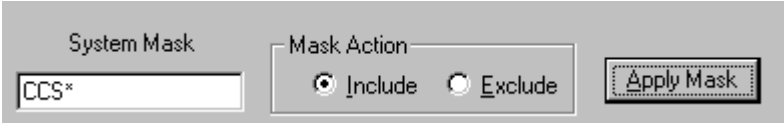
3.11 Lists and Masks

◆ List Boxes

Many dialogs in SAPHIRE contain list boxes. In some list boxes, multiple items can be selected for processing. An item in a list is selected if it is highlighted. There are various ways to select items from a list.

- ◇ To select a single item, click with the left mouse button on the desired item and let go of the mouse button.
- ◇ To select multiple contiguous list items, you can click with the left mouse button on the first desired item and drag up or down the list to the last desired item and then let go of the mouse button. Alternately, click the first desired item then, holding down the Shift key, click the last desired item.
- ◇ To select multiple non-contiguous items in the list, click several items while holding down the Control key.

◆ Masks



The screenshot shows a dialog box with a light gray background. On the left, there is a text field labeled 'System Mask' containing the text 'CCS*'. To the right of this field is a section labeled 'Mask Action' containing two radio buttons: 'Include' (which is selected) and 'Exclude'. To the right of the 'Mask Action' section is a button labeled 'Apply Mask'.

Some dialogs with list boxes provide a “Mask” capability which allows the user to select items from the list based on matched criteria. Generally, the mask is applied to the name of the item (e.g. System name or Event Tree name). To use the mask capability,

- ① In the mask entry field type the common characters of the names you wish to match. The wildcard characters, asterisk (*) and question mark (?), can be used in the mask. The asterisk represents one or more characters that a group has in common. The question mark represents a single character in that position of the string that a group has in common.
- ② Click either the Include or Exclude radio button, depending on whether you want these items included in the selection or excluded from it.
- ③ Choose the Apply Mask button. All list items with names matching your mask will be selected/deselected.

3.12 Pop-up Menus

Many dialogs in SAPHIRE have pop-up menus available. Once the dialog has been called up, invoke the pop-up menu by pressing the right-hand side mouse button. This is referred to as “clicking the right mouse button”. Pop-up menus for any one dialog may vary, especially when the dialog contains a multiple-select list box. The options in a pop-up menu are often dependent upon whether or not, or how many, items are selected.

4. BUILDING EVENT TREES

Section 4 introduces event tree **terminology** and SAPHIRE event tree **modeling conventions**. You will learn how to enter an event tree into SAPHIRE using the **graphical event tree editor** and also how to edit an existing event tree.

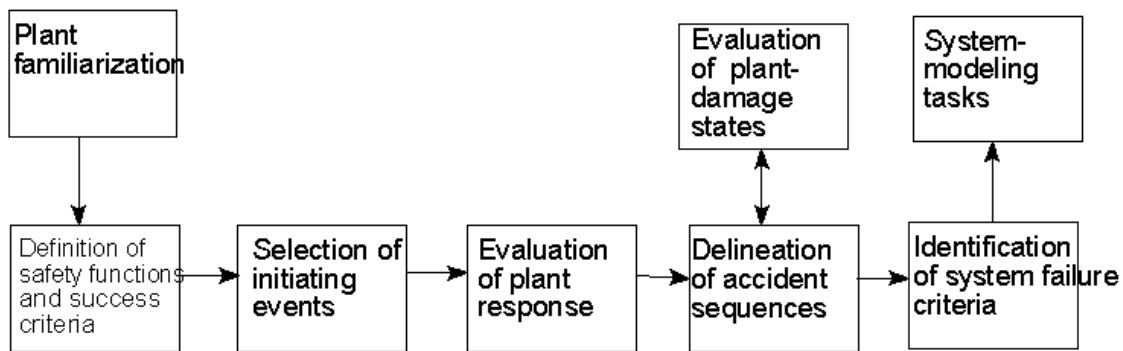
4.1 Event Tree Development

Event trees are developed by starting with an **initiating event** and **branching** to the right as various safety functions are questioned for success (up branch) or failure (down branch).

Event trees provide a traceable way to perform the following functions:

- ◆ Identify **accident sequences**
- ◆ Identify essential safety system functions
- ◆ **Quantify sequence** frequencies

Event Tree Development Process



Event Tree Definition

Event trees are logical representations of significant plant responses to **initiating events** with each **sequence** resulting in either a safe condition (such as safe shutdown) or an accident condition (such as core damage).

4.2 Event Tree Terminology

◆ Initiating Event

An initiating event is an operational occurrence (such as a LOCA or transient) which threatens fuel safety and may require safety system response to avoid core damage.

◆ Top Event

Safety systems (or human actions) which are intended to respond to the **initiating event**.

◆ Branching

The branching underneath a **top event** which indicates success with an up branch and failure with a down branch.

◆ Pass

When there is no **branching** beneath a **top event**, then the top event is not relevant to the particular **sequence**.

◆ Sequence

The **branching** path, from **initiating event** to **endstate**, that is a unique combination of system failures and/or successes.

◆ Endstate

Groups of **accident sequences** which share certain characteristics that the analyst delineates. These may be related to ability to perform selected safety functions or timing of functional failures.

4.3 SAPHIRE Event Tree Conventions

- | | | | |
|---|------------------|---|--|
| ◆ | Event Tree Names | □ | Event tree names may be up to 24 characters. The event tree name does not have to be the same as the initiating event name. |
| ◆ | Top Event Names | □ | 24 characters allowed. |
| ◆ | Initiating Event | □ | Only 1 initiating event allowed per event tree. |
| ◆ | OK, @, Success | □ | If the endstate column entry is OK, @, or Success, logic for that sequence will not be developed, and the sequence will not be analyzed. |

- ◆ Branch □ SAPHIRE always uses success for the up branch and failure for the down branch.
- ◆ Transfer Trees □ An event tree can branch to another event tree by using transfers. You must indicate that a transfer is to be invoked and specify the transfer event tree file name. The first top event in the transfer tree is ignored by the calling tree.
- ◆ Do not use *, ?, \, @, /, or space in naming SAPHIRE event trees or top events.

Example Event Tree

Loss of Offsite Power Initiating Event	Emergency Cooling	Containment Cooling	SEQ #	ENDSTATE
LOSP	ECS	CCS		
			1	OK
			2	SMALL—RELEASE
			3	LARGE—RELEASE

4.4 Event Tree Graphics Features Guide

Beginning the editing session

- ◆ To develop a new event tree
 - SAPHIRE menu bar: **Event Tree**
 - Event Tree List* dialog pop-up menu: **Add Event Tree**
- OR

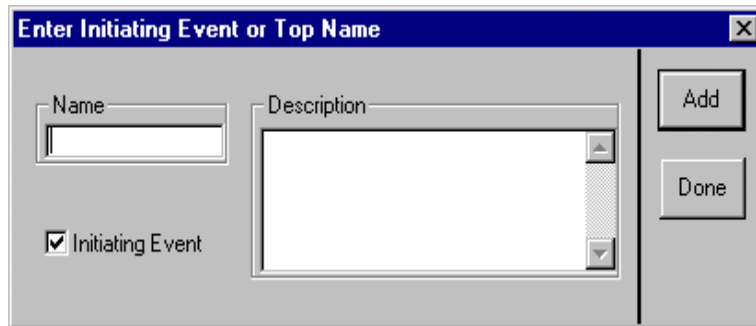
The screenshot shows a dialog box titled "Event Tree". It has a blue title bar with a question mark icon and a close button (X). The dialog contains two text input fields: "Name" and "Description". To the right of the "Name" field is a dropdown menu labeled "Initiator" which is currently set to "LOSP". At the bottom of the dialog are two buttons: "Ok" and "Cancel".

Enter the event tree name, initiating event name and provide any event tree description then press Ok.

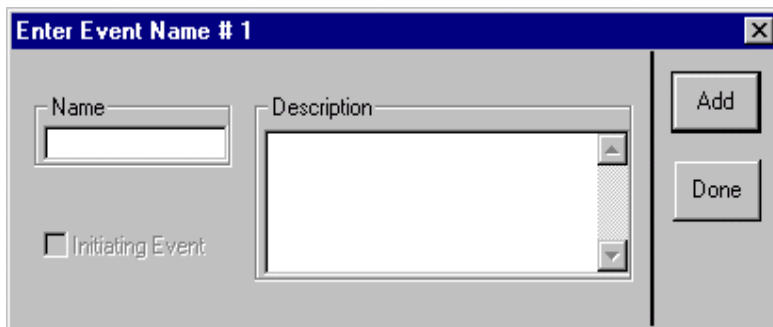
Event Tree List dialog pop-up menu: **Edit Graphics**

Event Tree Editor menu bar: **File → New** (Now proceed as discussed below.)

Event Tree List dialog pop-up menu: **Edit Graphics**



Enter the initiating event name and select the Initiating Event check box. (If creating a transfer tree, you may deselect the check box when the first event is not an initiating event.)



Continue by specifying **top event** names (from left to right on your event tree). When you have entered all the top events, choose Done on a blank *Enter Event Name #* dialog.

- ◆ To edit an existing file

SAPHIRE menu bar: **Event Tree**

Event Tree List dialog: Highlight the desired event tree name.

Event Tree List dialog pop-up menu: **Edit Graphics**

Editing event tree branches

- ◆ To add **branches** to event trees

Select the branch point then add a branch by either

Event Tree Editor menu bar: **Edit → Add Branch Above**,

OR Choose the **Add Branch Above** button  on the tool bar

A new branch will appear in the tree above the selected branch.



- ◆ To delete an unwanted branch

Use the mouse to select the unwanted branch

Event Tree Editor menu bar: **Edit → Delete**

Editing top events

- ◆ To add a **top event**


Choose the Top object button  from the button bar. The cursor will change to the Top cursor .

Move the cursor to the top in the header that will follow the top you are adding.

To add a top after the rightmost top, move the cursor to the right of the last top.


Click the mouse. The **Edit Event** dialog will be displayed

- ◆ To delete a top event

Select the top using the Pick  cursor.

Choose Delete from the Edit menu or press the Delete key

- ◆ To modify top event

Select the top using the Pick  cursor.

Right-click. The **Edit Event** dialog will be displayed

The Edit Event Dialog

This dialog is displayed any time a top is added or modified.



The **Edit Event** dialog box is shown with the following fields and controls:

- Name:** A text field containing "ECS".
- Description:** A text area containing "Emergency Cooling".
- Initiating Event:** An unchecked checkbox.
- Top Attributes:**
 - NAME display width:** A text field with "15" and the unit "characters".
 - DESCRIPTION display height:** A text field with "3" and the unit "lines".
 - Name Font:** A button to the right of the NAME display width field.
 - Desc Font:** A button to the right of the DESCRIPTION display height field.
 - Top Background Color:** A color selection field showing "Gray".
- Page Attributes:**
 - Background Color:** A color selection field showing "Blue".
 - Line Color:** A color selection field showing "Red".
 - Highlighted Sequence Color:** A color selection field showing "Black".
 - Leaf Height:** A text field with "30".
- Buttons:** "OK" and "Cancel" buttons at the bottom right.

Name - The name of the top. Maximum of 24 alphanumeric characters.

Description - Brief description of the top. Maximum of 600 alphanumeric upper- can lowercase characters.

Initiating Event - Select this check box if the top is an initiating event. (Only enabled on the first or leftmost top.)

Top Attributes

Display Name Count - The number of characters of every top name to display.

Description Lines - The number of lines of every description to display.

Name Font - The font size of every top event name in true fonts.

Description Font - The font size of every top event description in true fonts.

Top Background Color – The background color for the top header.

Page Attributes

Background Color - The background color for the event tree screen.

Line Color – The branch line color.


Leaf Height – The branch spacing in true font size.


OK - Apply the addition of or modifications to the top and close the *Edit Event* dialog.

Cancel - Close the *Edit Event* dialog without applying the addition of or modifications to the top.

Editing/Adding Endstates


- ◆ To modify sequence columns (or turn on endstate and sequence headers)

Choose the Pick button .

Position the Pick cursor  over the sequence header field.


Right-click. The *Edit Sequence Header* dialog will be displayed (see figure below).


- ◆ To enter either endstate names or sequence names


Select the desired sequence branch using the Pick  cursor left-click.

Right-click. The *Edit Sequence* dialog will be displayed.

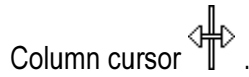
- ◆ To move a header on the graphic (for example, to shift the endstate column to the left)

Choose the Pick button .

Position the Pick cursor  over line to the left of the desired column.

The cursor will change to the Header cursor .

Drag the mouse to the desired location. The cursor will change to the Move



Column cursor .

Release the mouse and the column will be moved to the new location.

Edit Sequence Header Dialog

Change the sequence information column header in the diagram.

First - The sequence header. Maximum 24 alphanumeric characters. This column will always contain the sequence names. Select the check box to the left of this field to display this column.

Second - The sequence end state header. Maximum 24 alphanumeric characters. This column will always contain the end state or transfer tree names. Select the check box to the left of this field to display this column.

Third - The header for the third sequence column. Maximum 24 alphanumeric characters. This can be used for whatever information you wish, however, options exist elsewhere in the program that will put the frequency of this sequence in this column. Select the check box to the left of this field to display this column.

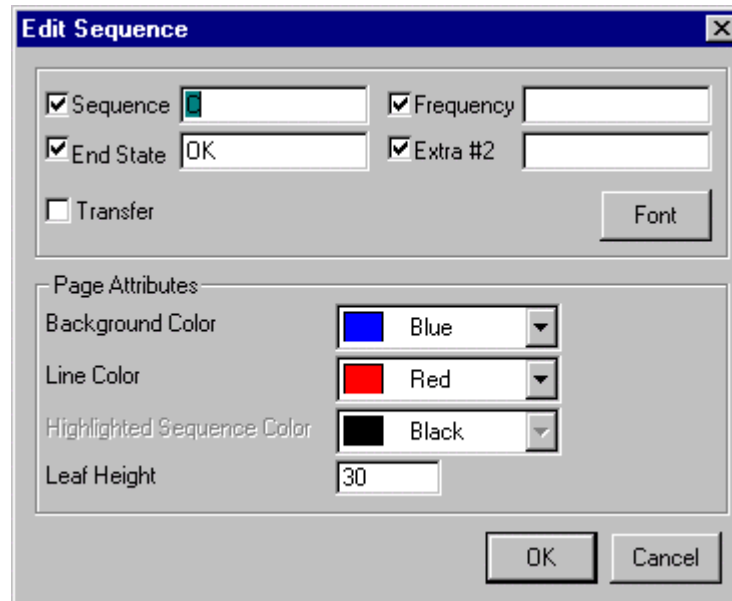
Fourth - Extra information for the sequence. Maximum 24 alphanumeric characters. This can be used for whatever information you wish. Select the check box to the left of this field to display this column.

OK - Close the *Edit Sequence Header* dialog and apply the changes the diagram.

Cancel - Close the *Edit Sequence Header* dialog without applying the changes to the diagram.

Edit Sequence Dialog

Each sequence path has some additional information that can help define it. This information includes the name of the sequence, the end state of this sequence, its frequency, and a user defined field. If the sequence continues through another event tree then the end state is the name of the transfer tree. You have an option to display this additional information and change its location.

The image shows a Windows-style dialog box titled "Edit Sequence". It has a standard title bar with a close button (X). The dialog is divided into two main sections. The top section contains four checked checkboxes: "Sequence", "End State", "Frequency", and "Extra #2". Each checkbox is followed by a text input field. The "Sequence" field contains a small green square icon. The "End State" field contains the text "OK". To the right of these fields is a "Font" button. Below this section is a "Transfer" checkbox, which is currently unchecked. The bottom section is titled "Page Attributes" and contains four items: "Background Color" with a blue color swatch and a dropdown menu showing "Blue"; "Line Color" with a red color swatch and a dropdown menu showing "Red"; "Highlighted Sequence Color" with a black color swatch and a dropdown menu showing "Black"; and "Leaf Height" with a text input field containing the number "30". At the bottom right of the dialog are "OK" and "Cancel" buttons.

Sequence - The name of the sequence. Maximum of 24 alphanumeric characters. Select the check box to the left of this field to display this column.

End State - The name of the sequence end state. Maximum of 24 alphanumeric characters. Select the check box to the left of this field to display this column.

Frequency - Extra information column #1 for the sequence. Can contain the frequency for the sequence. Maximum 24 alphanumeric characters. Select the check box to the left of this field to display this column.

Extra #2 - Extra information column #2 for the sequence. Maximum 24 alphanumeric characters. Select the check box to the left of this field to display this column.

Transfer - Check this box if the sequence continues in another event tree. The end state field contains the name of the transfer event tree.

Font - The font of the information text.

OK - Close the *Edit Sequence* dialog and apply the changes the diagram.


Cancel - Close the *Edit Sequence* dialog without applying the changes to the diagram.

Display adjustment

- ◆ To change the view of the event tree


From the *Event Tree Editor* menu bar select **View → Zoom**.

OR

Select the **Zoom** button  from the button bar.

OR

Press the **Ctrl+Z** key combination.

The cursor is changed to the Zoom cursor .

Move the cursor to the desired location.

To zoom in or magnify the diagram by 40%:

Click the mouse. The diagram will be magnified by 40%.

To zoom out or reduce the diagram by 40%:

Right-click the mouse. The diagram will be reduced by 40%.



- ◇ Use the scroll bars to change the portion of the diagram displayed in the window.

- ◆ To redraw the diagram

Event Tree Editor menu bar select **View → Refresh**.

Entering descriptive text


- ◆ To enter text (for a title or other description)

Choose the Text object  from the tool bar. The cursor will change to the Text cursor .

Position the text cursor at the desired location.


Click the mouse. The *Edit Text* dialog will be displayed.

- ◆ To move text

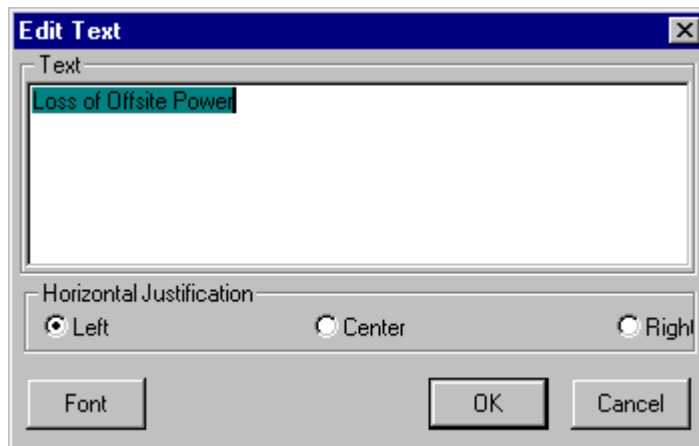
Select the desired text using the Text Pick cursor .

Drag the text to the new location.

- ◆ To modify existing text and attributes

Select the desired text using the Text Pick cursor .

Right-click. The *Edit Text* dialog will be displayed.



Text - Descriptive text for the event tree. Maximum of 600 alphanumeric upper- and lowercase characters.

Horizontal Justification - Set the horizontal alignment of the text.

Font - Choose the font to display this text in.


OK - Close the *Edit Text* dialog and add or modify the text in the diagram.

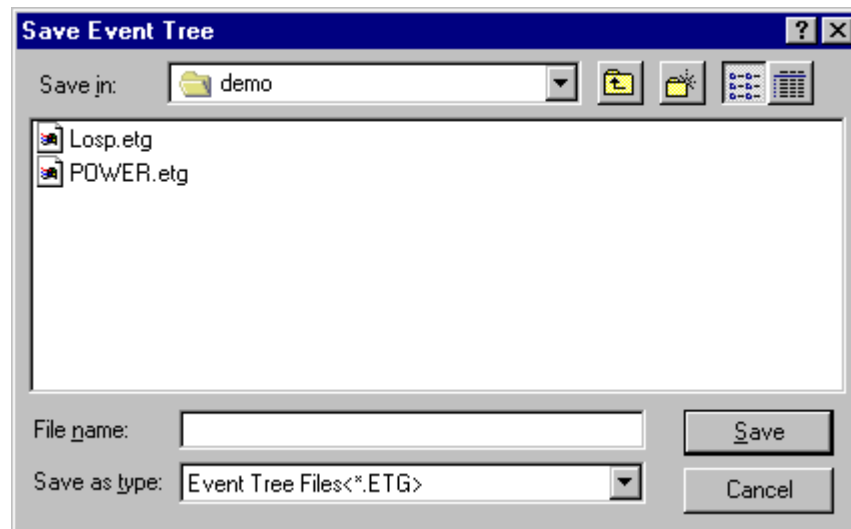
Cancel - Close the *Edit Text* dialog without adding or modifying the text in the diagram.

Ending the editing session

- ◆ To save the event tree

Event Tree Editor menu bar: **File → Save**,

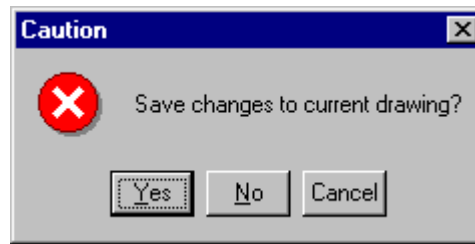
OR Choose the **Save Diagram** button  on the tool bar
Name the event tree file as directed.



- ◆ To exit without saving

Event Tree Editor menu bar: **File** → **Exit**

Choose **No** to quit without saving.



5. BUILDING FAULT TREES

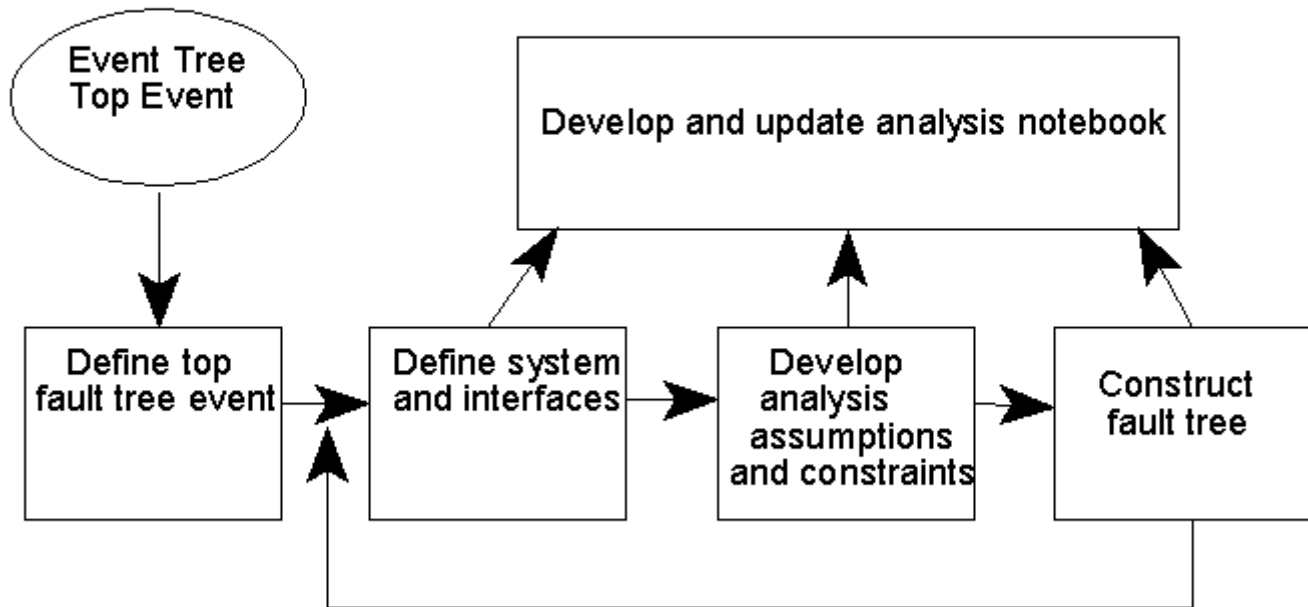
Section 5 introduces fault tree **development**, SAPHIRE fault tree **symbols**, and SAPHIRE fault tree **modeling conventions**. You will learn how to enter and edit fault trees by using the **fault tree text editor** and the **graphical fault tree editor**.

- ◆ Define the process of fault tree development and important terminology.
- ◆ Explain the various fault tree symbols used in SAPHIRE
- ◆ Using the fault tree graphics editor in SAPHIRE, construct a fault tree.
- ◆ Using the fault tree text editor in SAPHIRE, construct and edit a fault tree.

5.1 Fault Tree Development

Definition: Fault tree analysis is a deductive failure analysis method which focuses on identifying all of the credible ways that can cause an undesired **event** to occur. The undesired event is stated at the top of the fault tree. The fault tree **gates** specify the logical combinations of basic events that lead to the top event.

Fault Tree Development Process



5.2 Basic Event Symbols

Basic Event



Boxed Basic Event



Table of Basic Events



Undeveloped Event



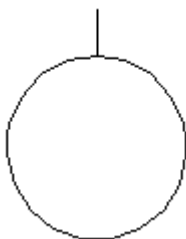
House Event



Undeveloped Transfer

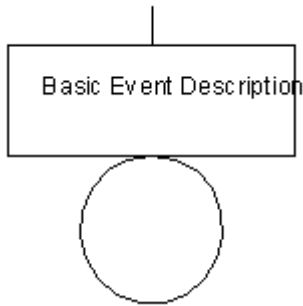


◆ Basic Event



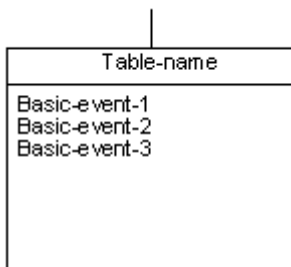
A basic event represents a fault such as a hardware failure, human error, or an adverse condition. The circle signifies that the fault event does not require further development.

◆ **Boxed Basic Event**



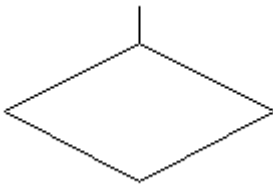
An alternate symbol for a **basic event** is a boxed basic event that provides a box to contain the description of the basic event.

◆ **Table of Basic Events**



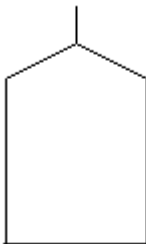
The table of basic events symbol allows up to 8 **basic events** to be entered in a space-saving layout. The logic used by the table is dictated by the **gate** it is connected to in the fault tree.

◆ **Undeveloped Event**



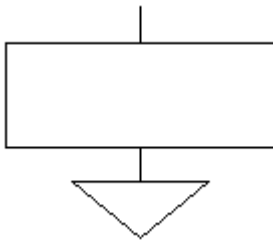
The undeveloped event denotes a **basic event** that is actually a more complex event that has not been further developed by fault tree logic. SAPHIRE treats this event no differently than a basic event.

◆ **House Event**



The house event is used to denote a failure that is guaranteed to always occur or never to occur. However, the calculation type assigned to a **basic event** establishes whether or not an event is a house event. Consequently, any basic event in SAPHIRE can be made into a house event.

◆ **Undeveloped Transfer**



The undeveloped transfer indicates that the event is complex enough to have its own fault tree logic developed elsewhere; however, the event has been treated as a **basic event** in the present fault tree.

5.3 Logic Gate Symbols



AND Gate



OR Gate



N/M Gate



Transfer Gate



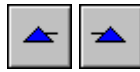
Inhibit Gate



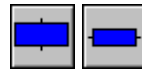
NOT AND
(NAND) Gate



NOT OR (NOR)
Gate



Right and Left
Transfer

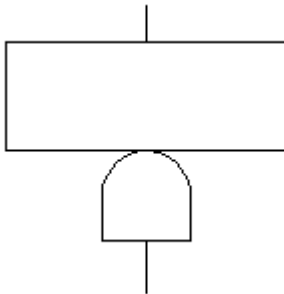


Vertical and
Horizontal Boxes



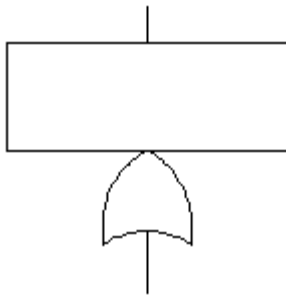
Connecting
Lines

◆ **AND Gate**



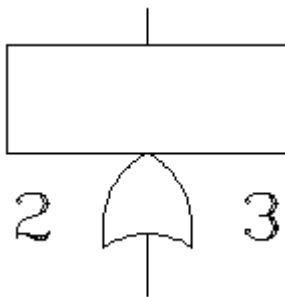
All inputs to the AND gate must occur for failure to occur.

◆ **OR Gate**



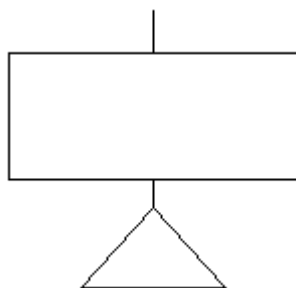
Any one input to the OR gate will cause failure to occur.

◆ **N/M Gate**



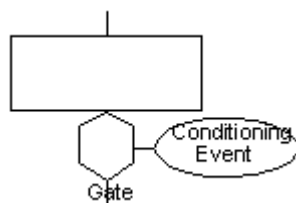
This gate states that N of the M input events must occur for failure to occur. For a 2/3 gate, any combination of 2 of the 3 input events must occur.

◆ **Transfer Gate**



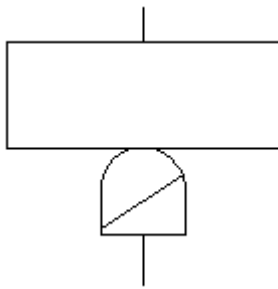
This gate is used to link logic structures together without introducing any new logic of its own. The transfer gate indicates that logic is continued on a new page (or on the same page). The transfer gate name is the same as the gate where the logic continues, and when transferring to another page (a separate fault tree file), the gate being transferred to must be the top gate on the page. (The top gate name of a fault tree must always be the fault tree filename.)

◆ **Inhibit Gate**



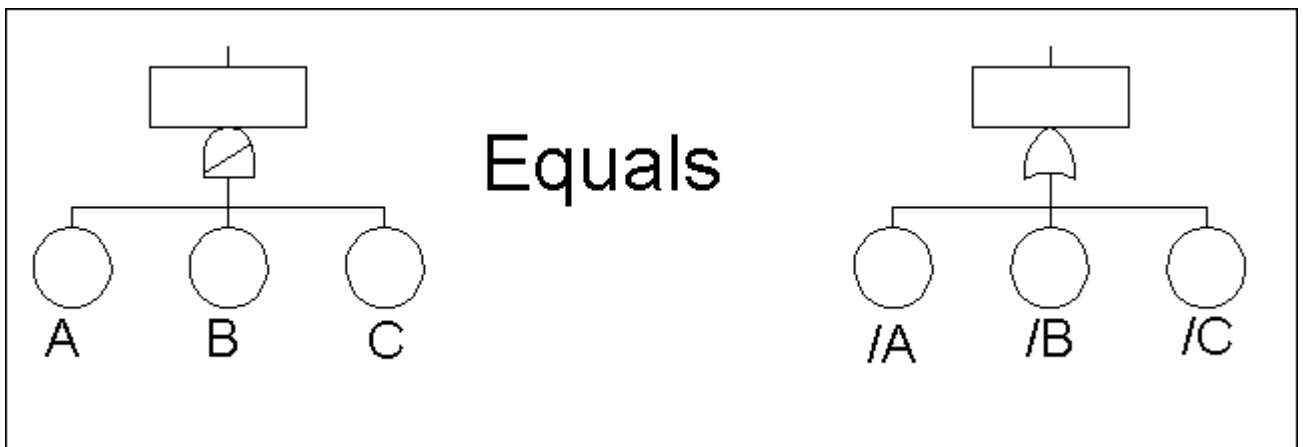
The output occurs if the single input fault occurs in the presence of an enabling condition. Thus, the inhibit gate is a special type of **AND gate**. The enabling condition (or conditioning event) is treated simply as a **basic event** with a probability or as a **house event**.

◆ **NOT AND (NAND) Gate**

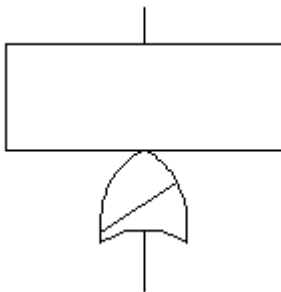


The output occurs if any one of the inputs does not occur. (See example.)

◆ **NAND Gate Example**

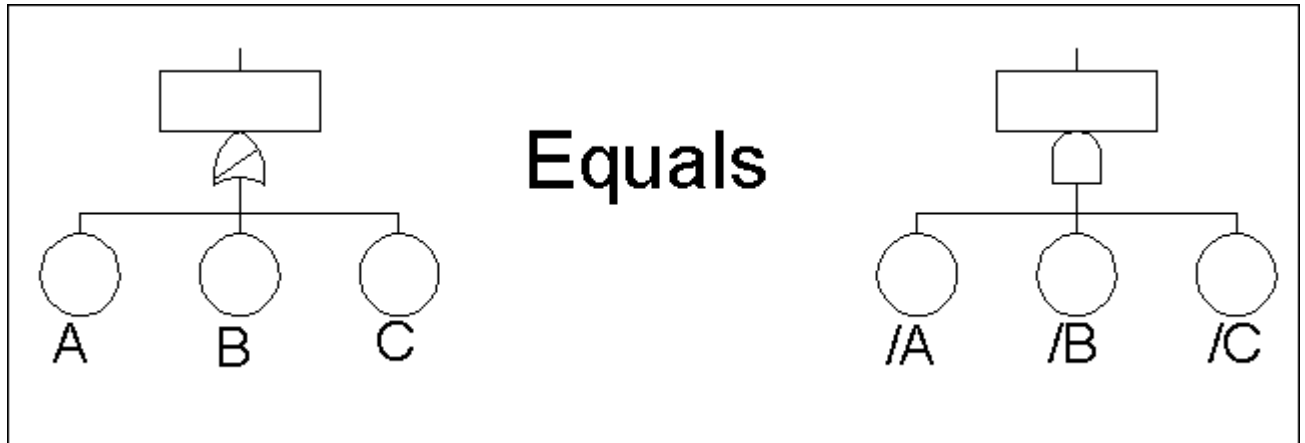


◆ **NOT OR (NOR) Gate**

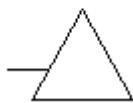
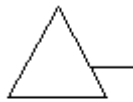


The output occurs if none of the inputs occur. (See example.)

◆ **NOR Gate Example**

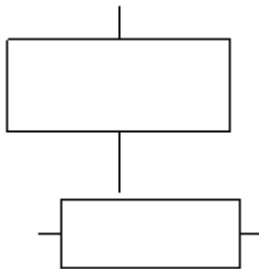


◆ **Right Transfer and Left Transfer**



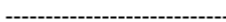
These symbols are used to indicate where a transfer has taken place.

◆ **Vertical and Horizontal Boxes**



A vertical or horizontal box is provided to allow further descriptive information to be placed in the diagram. SAPHIRE ignores these boxes when processing the fault tree.

◆ **Connecting Lines**



Connecting lines can be solid or dashed, or a dotted/dashed line. Connecting lines can be drawn at any angle. The connecting lines must actually touch the symbols being connected at the input or output stem on the symbol.

5.4 SAPHIRE Fault Tree Conventions

◆ Fault Tree File Name

The fault tree name **must** be the same as the top gate name. The fault tree name can be 24 characters long.

◆ Fault Tree Gates

24 characters allowed.

◆ Basic Event Names

24 characters allowed.

◆ Top Gates

A fault tree "page" or file can have only one top gate.

◆ SAPHIRE Default Naming

SAPHIRE will automatically assign basic event names (EVENTn) and gate names (GATEn); however, the user may replace the default name. These defaults may be changed on the *Preferences* dialog.

◆ Transfer Fault Trees

A fault tree can transfer to another fault tree by using transfer gates. The transfer gate name specifies the gate to transfer to. The transfer gate name must be the same as the gate name being transferred to. The gate being transferred to must either (1) be on the same page or (2) be the top gate of a separate fault tree file.

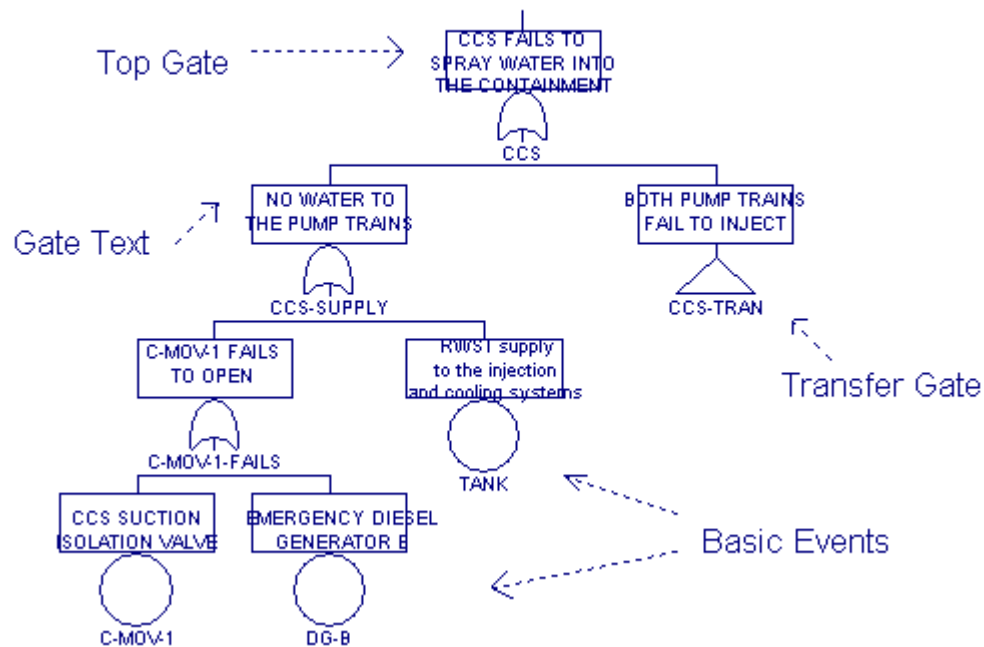
◆ Complemented Events

Complemented events can be input into fault trees by entering the basic event name with the "/" symbol, e.g., /DG-A.

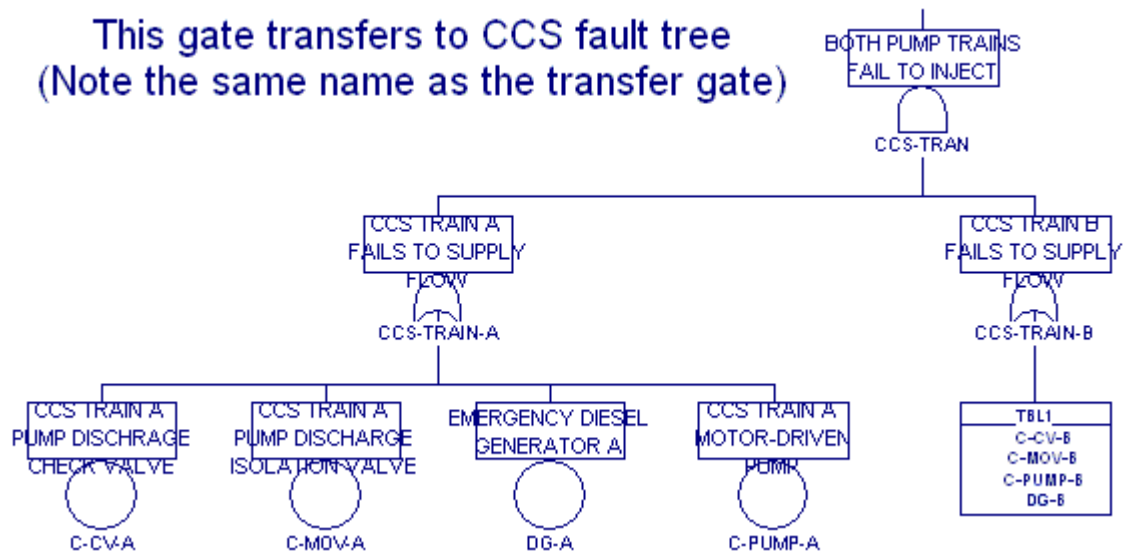
- ◆ Do not use *, ?, \, @, /, or space in the naming SAPHIRE fault trees or basic events. Note that the "/" symbol is used to denote a complemented event.

5.5 Example Fault Tree

Containment Cooling Fault Tree



This gate transfers to CCS fault tree
(Note the same name as the transfer gate)



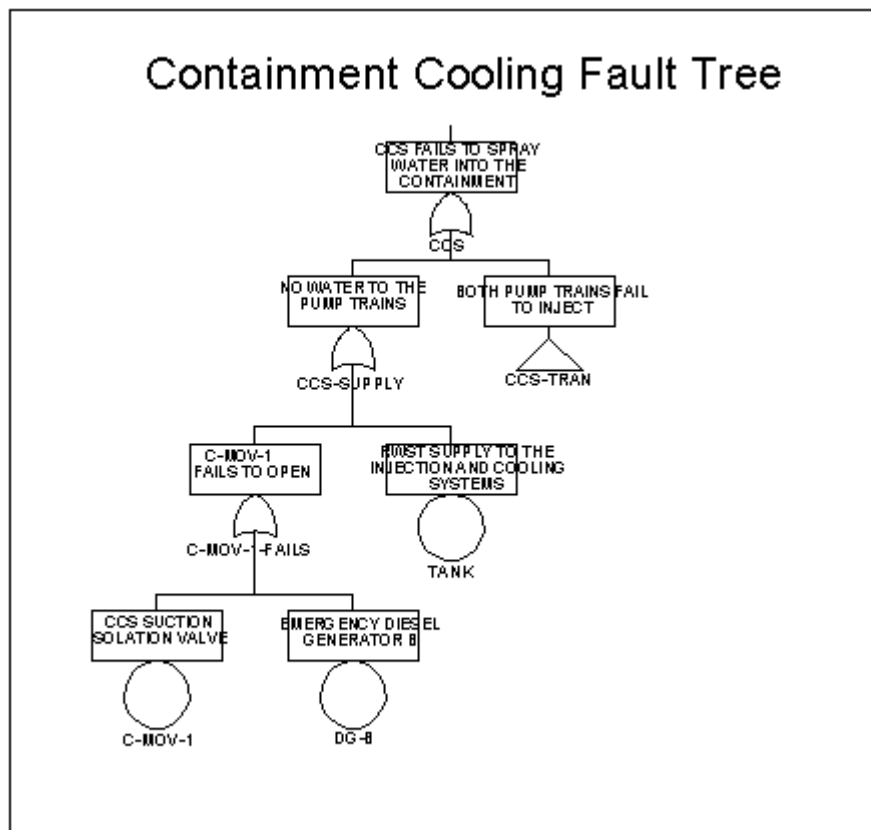
5.6 Fault Tree Logic Editor

The SAPHIRE fault tree **logic editor** allows you to modify the logic of a SAPHIRE fault tree (system or subsystem). Fault tree gate descriptions can be entered from this editor as well as basic event descriptions and data. The fault tree logic editor is a convenient tool for quickly editing fault tree logic and entering gate and basic event data.

The **logic format** for representing the fault tree logic is as follows:

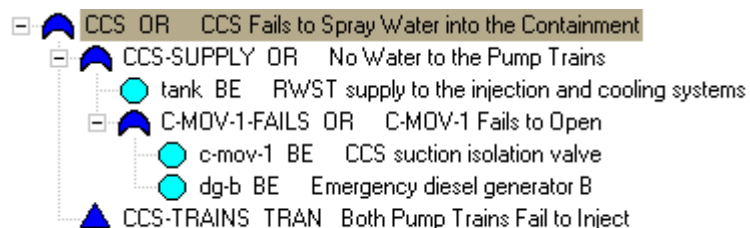
- ◆ Gates are listed on the left side of the screen.
- ◆ The type of gate (OR-gate, AND-gate, etc.) is specified to the right of the gate name.
- ◆ The gate inputs (basic events or gates) are listed to the right of the gate type.

Interpreting Fault Tree Logic Format

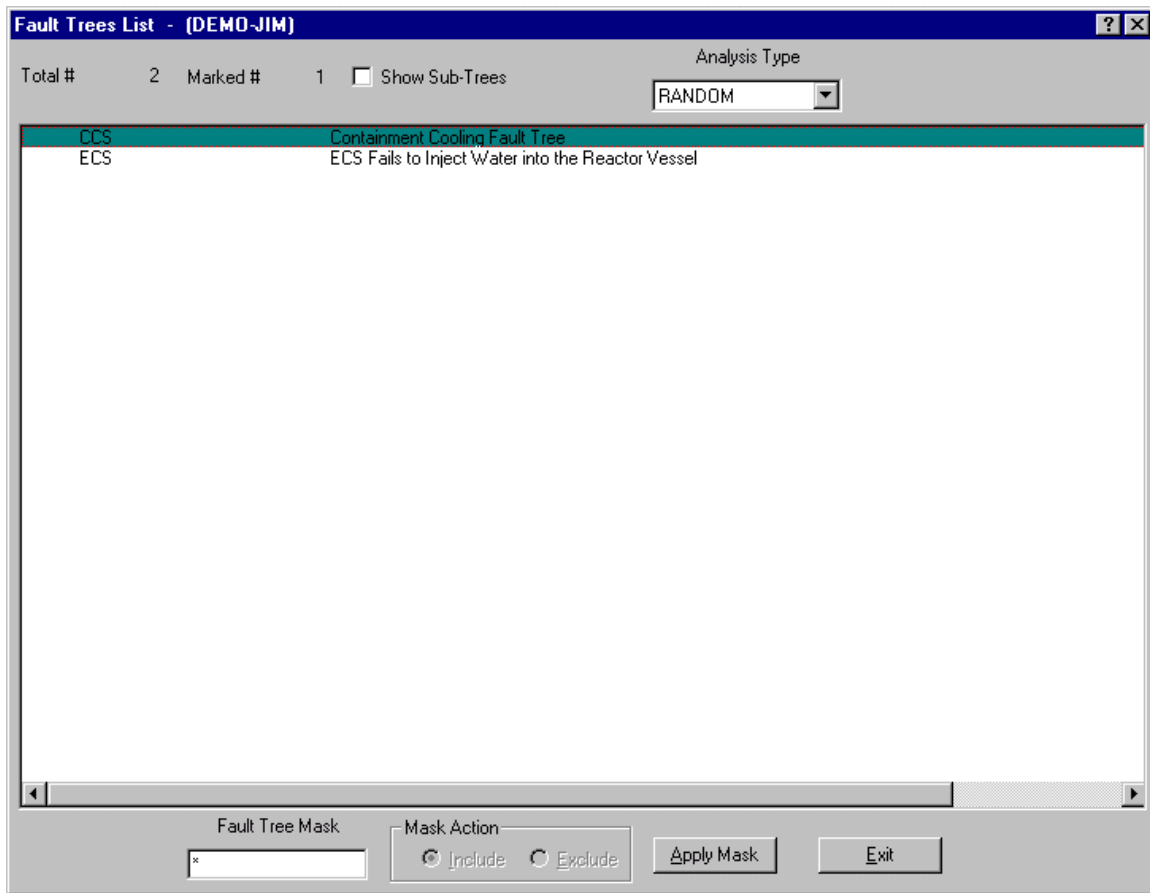


FAULT TREE LOGIC	
Gate Name	Type
CCS	OR
CCS-SUPPLY	OR
C-MOV-1-FAILS	OR
CCS-TRAN	TRAN

New logic editor...

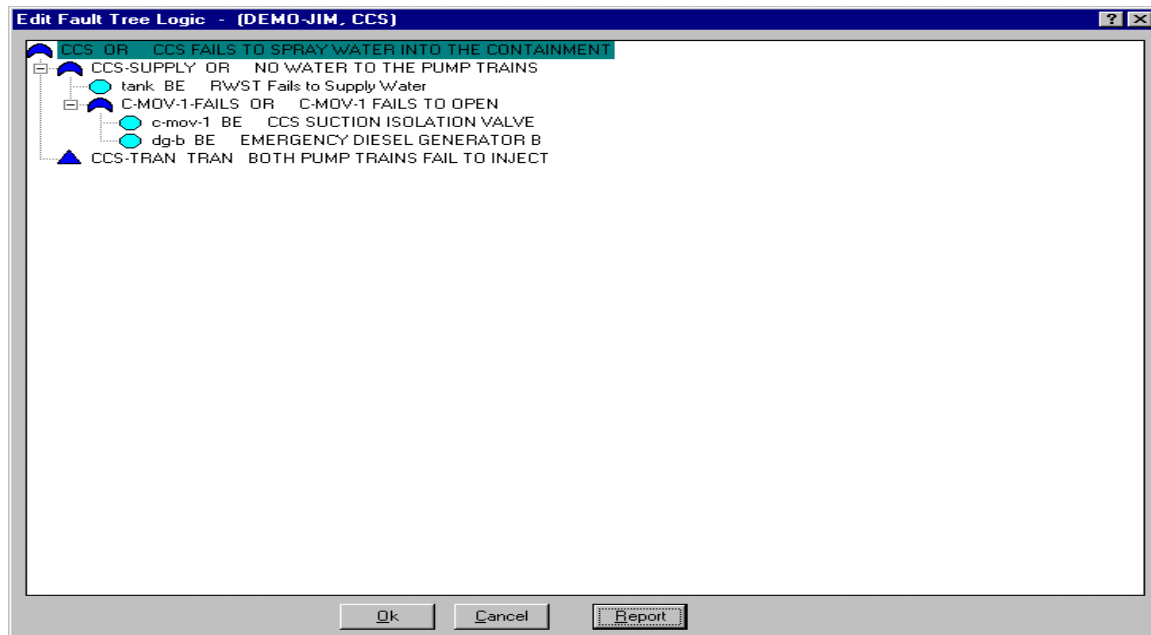


The System Logic Editor



- Select the **Fault Tree → Edit Logic** option.
- When you select this option, the *Systems List* dialog is displayed. The systems are shown in the list box. To display both systems *and subsystems*, select the Sub-systems check box. (Deselecting the Sub-systems check box will toggle the list so that only systems are displayed.)
- To **edit a system**, highlight the system and select Edit Logic from the pop-up menu. (Right-click to invoke the pop-up menu.)
- Systems are added to the database by adding tops to an event tree, by using **Modify → Systems → Add**, or by **Fault Tree → Add Fault Tree** to include the system.

The Logic Editor Display Screen



- The logic editor uses a hierarchical approach to editing the fault tree
- The logic can be expanded by pressing + or collapsed by pressing the -.
- To modify a basic event (or gate), highlight the gate it inputs to (click the right mouse) and select modify.

The 'Edit' dialog box is shown for the 'CCS-SUPPLY' gate. It contains the following fields and controls:

- Name:** CCS-SUPPLY
- Type:** Or
- Description:** NO WATER TO THE PUMP TRAINS
- Inputs:**

TANK	1.000E+000	RWST Fails to Supply Water
C-MOV-1-FAILS	OR	C-MOV-1 FAILS TO OPEN
- Buttons:** Add Event, Edit, Complement, Add Gate, Delete, Toggle Type, Ok, Cancel

- Highlight the basic event (or gate) and select **Edit**. Then modify its name, description, or probability.

Modify Event

Event | Attributes | Process Flag | Template | Transformations | Uncertainty

Event Names

Primary: TANK Alternate: TANK

Description: RWST Fails to Supply Water

Random Failure Data

Type: 1 : Probability

Mean Failure Probability: 1.000E-007

Lambda: +0.000E+000

Tau: +0.000E+000

Mission Time: +0.000E+000

Uncertainty Data

Type: Use point value

Correlation Class:

OK Cancel

- To add a gate (or basic event), highlight the gate it inputs to (click the right mouse) and select modify.
- Select the **Add Gate** option and type in the name of the new gate along with its type and description.

Gate

Name: CCS-NEW Type: And

Description: This is a new Gate

Ok Cancel

The following provides a list of the options available for adding or modifying both basic events or gates.

Add Event – Add event is used to add a new basic event as an input to the gate. This option allows for the basic event's description to be added along with its probability.

Add Gate – Add gate is used to add a new gate as an input to the gate highlighted. This option also allows for the gate's description to be added.

Edit – The edit option allows you to change a basic events name, description, and probability and change a gate's name, type, or description depending on which type of event is highlighted.

Delete – The delete option will delete the highlighted basic event or gate.

Complement – The complement option will complement any basic event that is highlighted.

Toggle Type – Toggle type will toggle the event highlighted between a basic event or a gate.

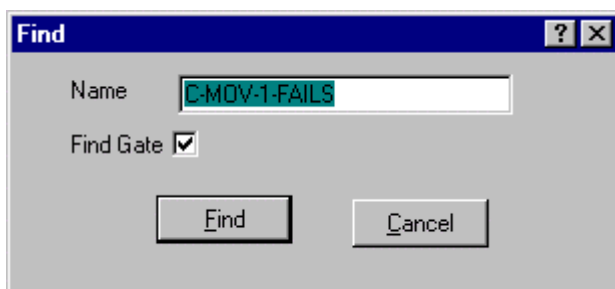
Ok – Close the Modify (Edit) fault tree dialog and apply the changes.

Cancel – Close the Modify (Edit) fault tree dialog without applying the changes.

Other Features of the Logic Editor

Find Option

- The find option searches the fault tree logic to find the specified basic event or gate.
- To find a basic event or gate (right click the mouse) and select **Find**. Type in the name of the gate or basic event and check the box if the search is for a gate and uncheck the box if the search is for a basic event. Press **Find**.



Move Option

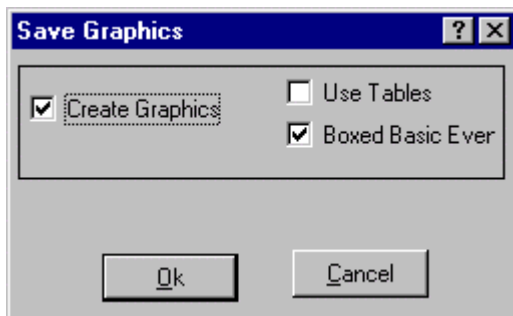
- The move option will move a gate and its logic from its original input gate to another selected gate.
- To move a gate highlight the gate (right click the mouse), select move and place cursor by the new gate and click the left mouse button. The gate and its associated logic will now be placed as an input to the new gate.

Transfer Option

- The transfer option transfers from the fault tree currently being edited to the fault tree specified by the transfer gate.
- To transfer from one fault tree to another highlight the transfer gate (right click the mouse) then select **Follow Transfer**.
- To transfer back, highlight the transfer gate (right click the mouse) then select **Transfer Back**.

5.7 Updating the Graphical Fault Tree (.DLS) File

After changes are made to fault tree logic using the Logic Editor, when you press **Ok** a dialog box will ask if you what to save the fault tree logic as a graphic file. At this point you can check the box and a graphic file will automatically be created. Or secondly, use the **Utility → Fault Tree → Alpha-to-Graphics** conversion to update the fault tree graphical file. (You do not have to update the graphical file in order to perform analyses with the updated logic; however, to keep the fault tree logic and the fault tree graphic identical, you must perform the Alpha-to-Graphics conversion.)




5.8 Fault Tree Editor Tips

- ◆ New fault tree "systems" cannot be added using the logic editor. Systems can be added by saving the new fault tree in the Fault Tree graphical editor, by entering the fault tree name as the top event in an event tree, or by adding it in **Modify → Fault Trees**, or by adding it in **Fault Trees → Add Fault Trees**. Subtrees are added in the editor when the Transfer gate type is used.
- ◆ The fault tree logic editor does not allow the user to save the edited fault tree with a new fault tree name. The top gate in the fault tree should match the fault tree name.
- ◆ It is not yet possible to retain special symbols that may be used with the graphical editor. Special basic event symbols (such as the undeveloped event and house event) will be changed to either round basic events or boxed basic events when the Alpha-to-Graphics conversion of fault tree logic from text is used to update the graphical file.

5.9 Fault Tree Graphics Features Guide

Beginning The Editing Session

- ◆ To develop a new fault tree
SAPHIRE menu bar: **Fault Trees**
Fault Tree List dialog pop-up menu: **Edit Graphics**
Fault Tree Editor menu bar: **File → New**
or
SAPHIRE menu bar: **Fault Trees**
Fault Tree List dialog pop-up menu: Add Fault Trees
- ◆ If you wish to edit an existing file while in the graphic editor
Fault Tree Editor menu bar: **File → Open**
OR Choose the **Open Diagram**  button on the tool bar.
Double-click on the fault tree filename you wish to edit.

Selecting and Arranging Logic Symbols

- ◆ To begin building a fault tree
Select the desired object button from the tool bar.
Then move the shape cursor to the desired location with the mouse and click the left mouse button.
Use the right mouse button to end the selection or menu option.

- ◆ To select objects

Choose the Pick button  to select a single object

Choose the Text Pick button  to select a text object.

Then click on the desired object.

A dashed line will appear surrounding the selected object(s).

- ◆ To delete unwanted objects

Select the object to be deleted (click on the shape with the left mouse button)

Fault Tree Editor menu bar: **Edit → Delete**

OR Choose the Delete key.

- ◆ To move symbols (and their associated text, if any)

Select the object to be moved

Drag the object to the desired location.

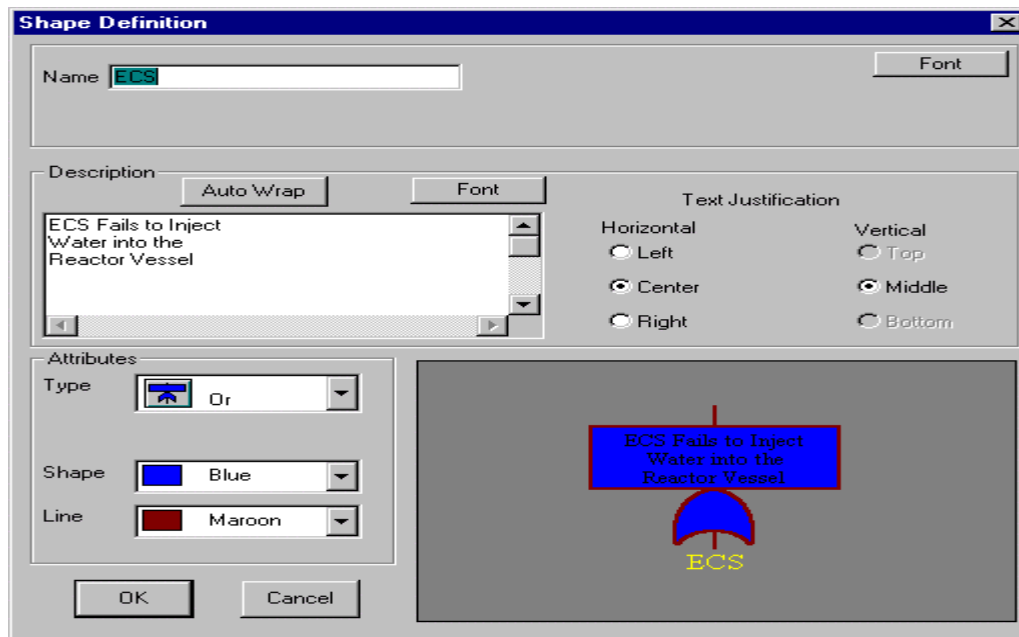
Naming Gates And Basic Events

- ◆ To rename logic or basic event symbols

Select the desired shape

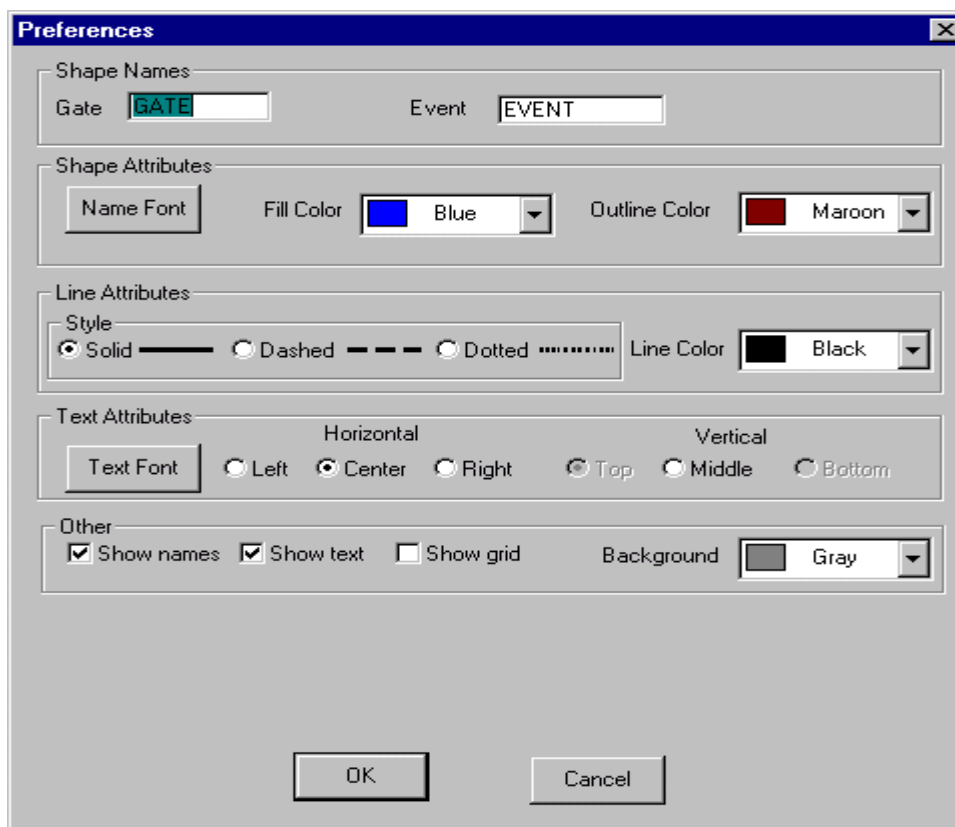
Fault Tree Editor menu bar: **Edit → Attributes**

OR right-click and choose **Edit**,



Then make desired changes.


- ◆ To view the current name of a gate or basic event
Fault Tree Editor menu bar: **View** → **Preferences**
OR right-click and choose **Edit Preferences**,



Check the **Show Name** check box and choose the **OK** button.

Connecting Symbols With Lines

- ◆ To link gates and basic events together

Select the **Line** button  from the tool bar. Drag from the starting location to the ending location.

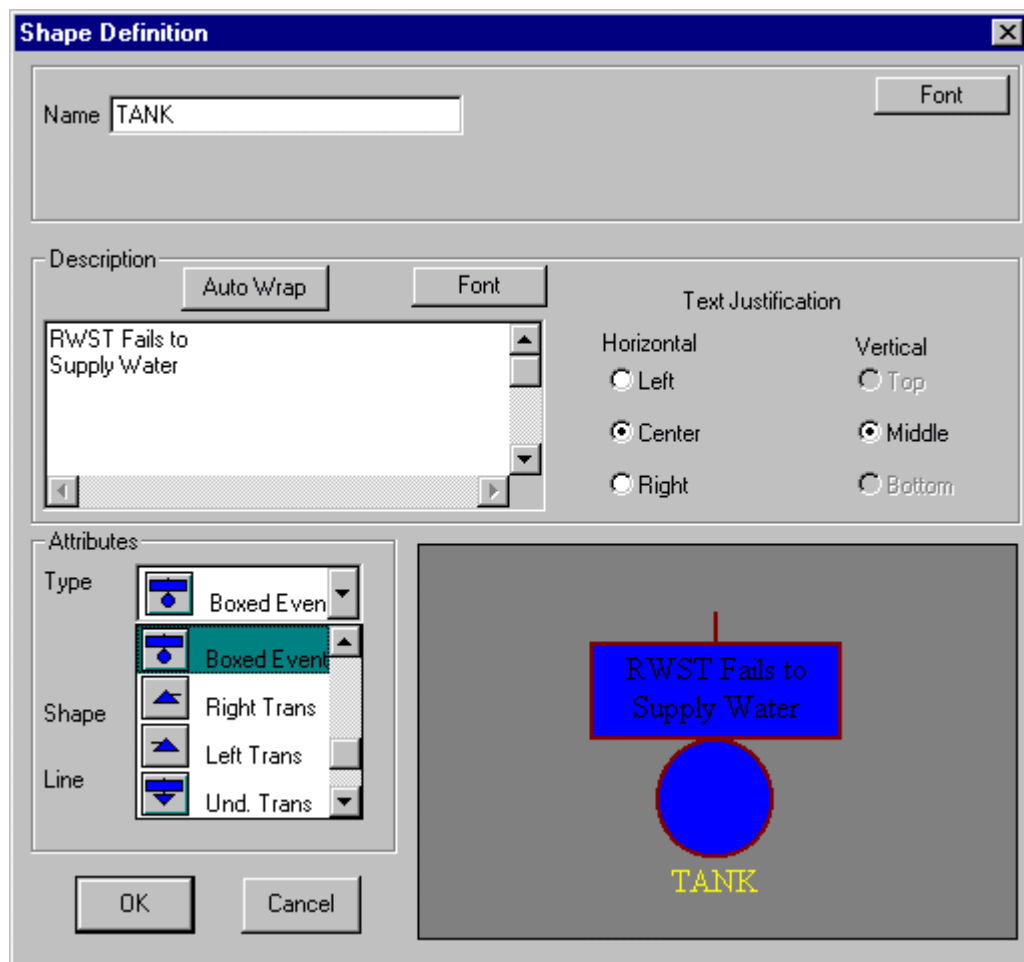
(Note: if you move symbols after connecting with lines, you may need to redraw the lines unless the lines were moved with the symbols.)

Changing Symbol Type

- ◆ To change a symbol (e.g., to change a basic event to an undeveloped transfer)

Select the shape

Fault Tree Editor menu bar: **Edit → Attributes**











Choose the **Type** button.

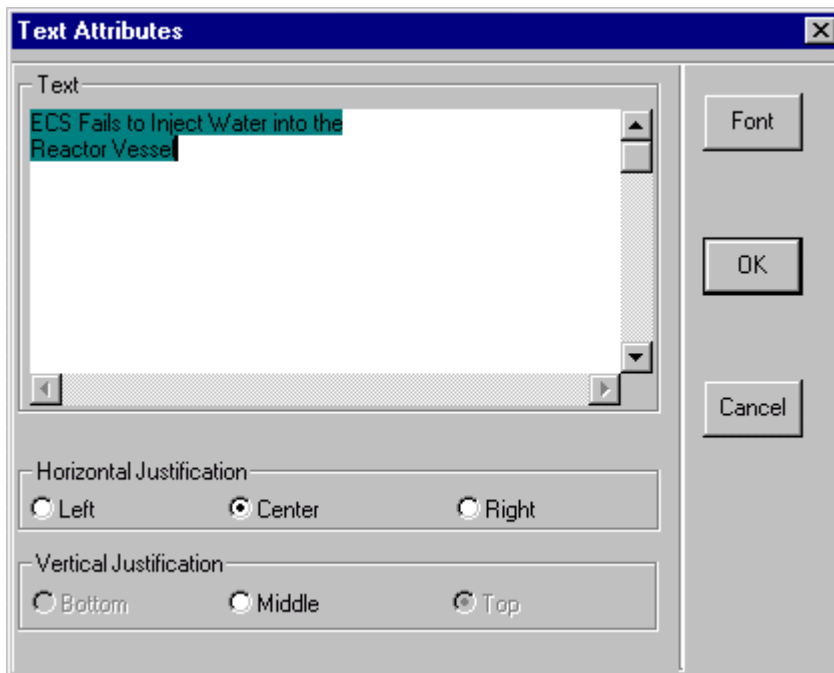
Select the new shape type from the list.

Display Adjustment

- ◆ To change the view of the event tree
Fault Tree Editor menu bar: **View**
 - Zoom** allows you to zoom in.
 - Page Up** allows you to move up one page.
 - Page Down** allows you to move down one page.
 - Page Left** allows you to move left one page.
 - Page Right** allows you to move right one page.
 - View Normal** resets the screen.
- ◆ To redraw the window
Fault Tree Editor menu bar: **View → Refresh**

Entering Descriptive Text

- ◆ To enter text (for a title or other description)
Choose the Text Object button  from the tool bar. The cursor will change to the Text cursor .
Position the text cursor at the desired location.
Click the mouse. The *Text Attributes* dialog will be displayed.
- ◆ To move the associated symbol only
Choose the Pick button  from the tool bar. The cursor will change to the Pick cursor .
Pick cursor .
- ◆ To move text only
Choose the Text Pick button  from the tool bar. The cursor will change to the Text Pick cursor .
Select the desired text.
Drag the selected text to the new location.
- ◆ To change existing text and attributes
Select the desired text using the Text Pick cursor .
Right-click and choose **Edit**. The *Text Attributes* dialog will be displayed.



Text - Descriptive text for a shape or explanatory text for the entire fault tree. Maximum of 600 alphanumeric upper- and lowercase characters.

Justification

Horizontal - The horizontal alignment of the text.

Vertical - The vertical alignment of the text.

Text Font - The font size or type for the text and the color of the text.

OK - Close the *Text Attributes* dialog and add the input text to the diagram.

Cancel - Close the *Text Attributes* dialog without adding the text to the diagram.

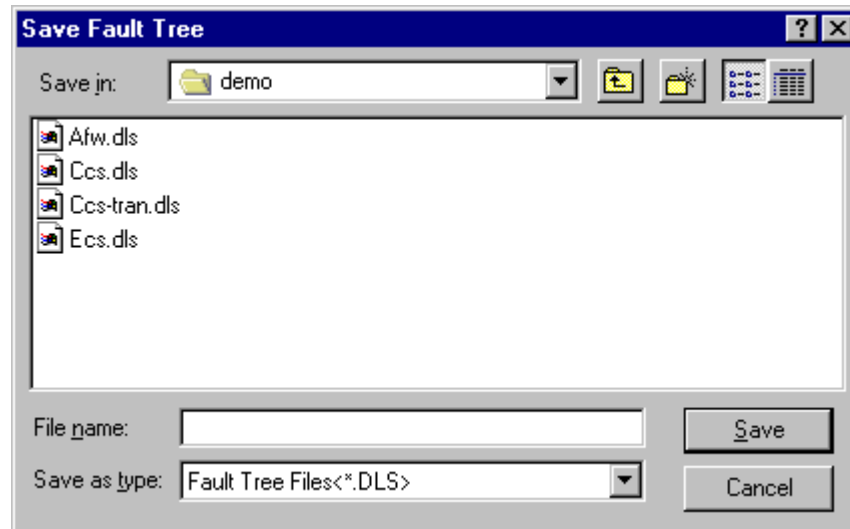
Ending The Editing Session

- ◆ To save the fault tree graphic

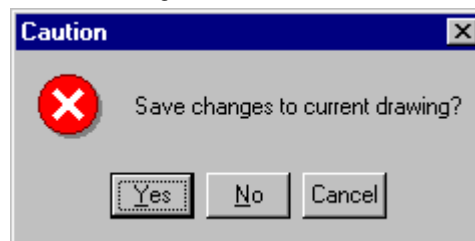
Fault Tree Editor menu bar: **File → Save,**

OR Choose the **Save Diagram** button  on the tool bar

Name the fault tree file as directed.



- ◆ To exit without saving
Event Tree Editor menu bar: **File** → **Exit**
Choose **No** to quit without saving.



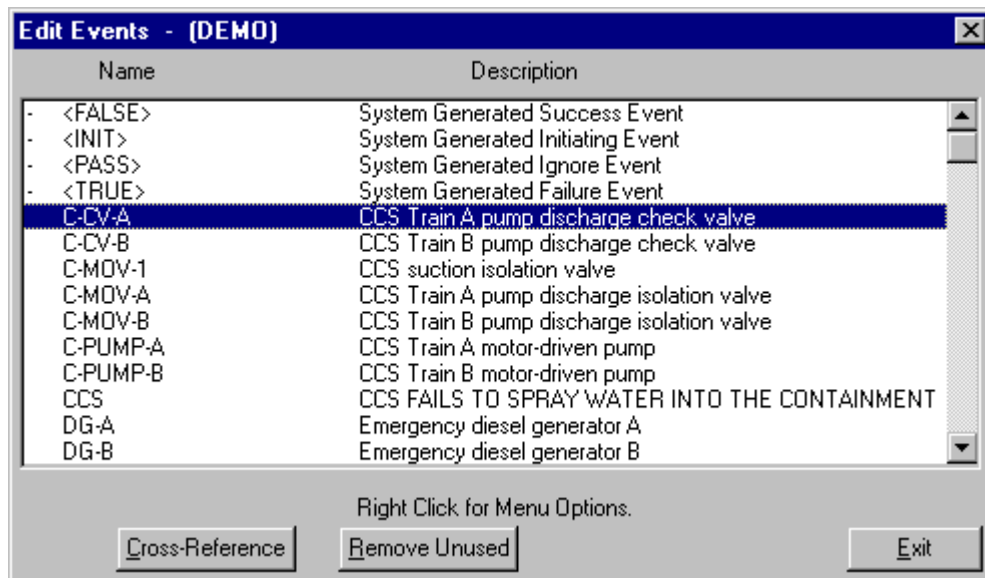
6. BASIC EVENT INFORMATION

Section 6 introduces SAPHIRE **basic event data entry** and basic event probability **calculation types**.

- ◆ Explain the various basic event data fields used in SAPHIRE.
- ◆ Provide definitions for basic event information terminology.
- ◆ Explain the seven basic event calculation types available in SAPHIRE.
- ◆ SAPHIRE provides four different “event” categories, define each of them.
- ◆ Using the Modify option in SAPHIRE, enter component basic event data.

6.1 Modify Basic Events

- To enter basic event data, select **Modify** from the menu. Then select **Basic Events**.



- To modify data for an existing event, double-click on the event you want to edit.
- To add a new event, right-click to invoke the pop-up menu and select the **Add** option.

6.1.1 Basic Event Data Fields

Modify Event

Event | Attributes | Process Flag | Template | Transformations | Uncertainty

Event Names

Primary: C-CV-A Alternate: C-CV-A

Description: CCS TRAIN A PUMP DISCHARGE CHECK VALVE

Random Failure Data

Type: 1 : Probability

Mean Failure Probability: 1.000E-004

Lambda: +0.000E+000

Tau: +0.000E+000

Mission Time: +0.000E+000

Uncertainty Data

Type: L : Log Normal

Error Factor: 3.000E+000

Correlation Class: 1

OK Cancel

Primary Name

The Primary name is the fundamental name used in the fault trees and event trees. A unique Primary name must be specified for every basic event in the logic models. A maximum of 24 uppercase, alphanumeric characters may be entered. Embedded blanks are not allowed. The name should be descriptive so it can be readily identified.

Alternate Name

The Alternate name, which can be different than the Primary name, can be used to report cut set results by selecting Alternate name in the **Define Constants** option. This feature allows cut sets to be reported using a different naming scheme that is more descriptive. A maximum of 24 uppercase, alphanumeric characters may be entered in this field. Embedded blanks are not allowed.

Description

This is a 60-character, uppercase or lowercase, alphanumeric field that provides brief, descriptive information.

Calculation Types

In the Failure Data section the calculation type is a numerical reference to the calculation method to be used. There are 17 calculation types numbered 1 through 9, T, F, I, S, G, L, M, and H. Choose the desired calculation type from the drop-down list.

An equation for each calculation type follows. See the [symbol table](#) for more details.

- 1 $P = p.$
The value specified in the Probability field is directly used as the basic event failure probability or initiating event frequency
- 2 This calculation type uses Calculation Type 3, below.
- 3 $P = 1 - \text{Exp} (-L * t_m).$
This calculation type is the full equation for the failure probability of an operating component without repair in a non-demand failure mode.
- 4 This calculation type uses Calculation Type 5, below.
- 5 $P = ([L * T] / [1 + \{L * T\}]) * (1 - \text{EXP} [-(L + 1 / T) * t_m]).$
This calculation type is the full equation for the failure probability of an operating component with consideration given to the ability to repair the component.
- 6 This calculation type uses Calculation Type 7, below.
- 7 $P = 1 + (\text{EXP}[-L * T] - 1) / (L * T).$
This calculation type is the full equation for the failure probability of a standby component in a non-demand failure mode with consideration given to periodic testing.
- T $P = 1.0$ (House event - failed).
This calculation type indicates that the basic event is to be treated as a house event that is always failed. A house event never appears in the minimal cut sets. The model is modified to reflect the logic, given that the indicated basic event is always failed. To do this for an event that is guaranteed to occur (failure probability = 1.0), the event is removed from the logic where it appears as an input to an AND gate. If the basic event is input to an OR gate, the entire gate and its inputs are removed from the logic. The resulting minimal cut sets show the failure combinations that must occur for top event or sequence failure given that the indicated basic event is always failed.
- F $P = 0.0$ (house event - successful).
This calculation type indicates that the basic event is to be treated as a house event that is never failed. A house event never appears in the minimal cut sets. The model is modified to reflect the logic given that the indicated basic event is never failed. To do this for an event that is guaranteed successful, the basic event is removed from the logic

- where it appears as an input to an OR gate. If the basic event is input to an AND gate, the entire gate and its inputs are removed from the logic. The resulting minimal cut sets show the failure combinations that must occur for top event or sequence failure given that the indicated basic event can never fail.
- I $P = 0.0$ (ignore event).
This calculation type indicates that the basic event is to be treated as if it did not exist in the logic for the fault tree. Before the tree is solved, the logic is edited to remove all references to the specified event from the fault tree.
 - S $P = 0.0$ (find a system with the same name and use its current mincut upperbound as the probability)
This calculation type indicates that the basic event is to replace its matching system. If no matching system exists, the probability will be set to 0.0.
 - G $P = \Phi[\ln(g/a)/Br]$.
This calculation type indicates that the basic event is to be treated as a seismic event. The probability value for screening will be calculated using the ground acceleration, failure acceleration, and Br entered by the user.
 - H $P = \Phi[\ln(g/a)/Br]$.
This calculation type indicates that the basic event is to be treated as a seismic event. The probability for screening will be calculated from the failure acceleration, Br, and ground acceleration. The ground acceleration will be the highest g-level specified in the medium project hazard curve.

Calculation Type Equation Symbols

The following symbols are used in the equations for calculating failure probability:

- P = failure probability of the basic event,
- p = failure probability,
- bp = base case failure probability,
- L = failure rate per hour, input as lambda,
- tm = mission time expressed in hours, input as a default,
- T = average time to repair expressed in hours, input as tau,
- Φ = standard normal cumulative distribution function,
- a = median killer acceleration (the approximate ground acceleration sufficient to cause the component to fail),
- Bu = confidence level that "a" is really the median killer acceleration,
- Br = the amount the killer acceleration "a" can vary
- ln = natural log
- g = ground acceleration for screening.

Mean Failure Probability

Enter the probability that a component will fail between t and $t + \Delta t$ given that no failure has occurred before time t (use scientific notation).

Lambda

Enter the event's failure rate per hour (use scientific notation).

Tau

Enter the average time to repair in hours (use scientific notation).

Mission Time

Enter the mission time in hours (use scientific notation). The mission time is the period of time that a component is required to operate in order to characterize the component operation as being successful.

An example would be for a pump that must run for 24 hours after a particular initiating event occurs. The mission time for this case would be 24 hours.

Distribution Types

For the Uncertainty Data section, there are eleven predefined distribution types available. The predefined distribution types are:

normal, lognormal, beta, dirichlet, gamma, chi-squared, exponential, uniform, maximum entropy, and seismic.

In addition to these predefined distribution types, user-defined histograms may be used. The default distribution type is no distribution. Choose the desired distribution type from the drop-down list.

Value 1

Enter the first parameter of the distribution, if one is required.

Value 2

Enter the second parameter of the distribution, if one is required.

Correlation Class

Use to account for data dependencies among like events in the database. Enter up to four uppercase, alphanumeric values. A blank correlation class indicates that there are no data dependencies. When running the uncertainty analyses, the same sample value will be used for all basic events with the same correlation class.

SAPHIRE Failure Data Entry Requirements

Calculation Type	Mean Failure Probability	Lambda*	Tau	Mission Time
1	✓			
2,3		✓		✓**
4,5		✓	✓	✓**
6,7		✓	✓	

Notes: * The units of lambda, tau, and mission time must be the same so that they cancel.

** If no mission time is specified (i.e., the mission time is zero), the default mission time specified in SAPHIRE **Utilities → Define Constants** will be used.

6.1.2 Basic Event Attributes

Susceptibilities		
Random	<input checked="" type="checkbox"/>	User1 <input type="checkbox"/>
Fire	<input type="checkbox"/>	User2 <input type="checkbox"/>
Flood	<input type="checkbox"/>	User3 <input type="checkbox"/>
Seismic	<input type="checkbox"/>	User4 <input type="checkbox"/>
Initiating Event	<input type="checkbox"/>	User5 <input type="checkbox"/>
Condition	<input type="checkbox"/>	User6 <input type="checkbox"/>
Reserved3	<input type="checkbox"/>	User7 <input type="checkbox"/>
Reserved4	<input type="checkbox"/>	User8 <input type="checkbox"/>

Comp Id

Component Identifier. Enter up to seven (7) alphanumeric characters to identify a component by a unique designator. This is usually part of the component label (e.g., DG01). No embedded blanks are allowed.

System

Enter up to three (3) alphanumeric characters to identify the system containing the component.

Train

Enter up to two (2) alphanumeric characters to identify the train containing the component.

Type

Enter the event type attribute.

Failure Mode

Enter up to two (2) alphanumeric characters to identify the failure mode for the component.

Location

Enter up to three (3) alphanumeric characters to identify the physical location for the component.

Susceptibilities

The susceptibility flags indicate whether or not the event is susceptible to a specific kind of failure. There are 16 susceptibilities as defined below:

- | | | |
|--------|---|--|
| 1 | = | Random (default) |
| 2 | = | Fire |
| 3 | = | Flood |
| 4 | = | Seismic |
| 5 | = | Reserved 1 (Initiating Event Assessment) |
| 6 | = | Reserved 2 (Condition Assessment) |
| 7 | = | Reserved 3 |
| 8 | = | Reserved 4 |
| 9 - 16 | = | User-defined |

Susceptibility flags must be checked to be considered susceptible to a specific type of failure. All events are susceptible to random failure regardless of the random flag's value.

Category

Select the from the drop-down list to specify the category or use of the event.

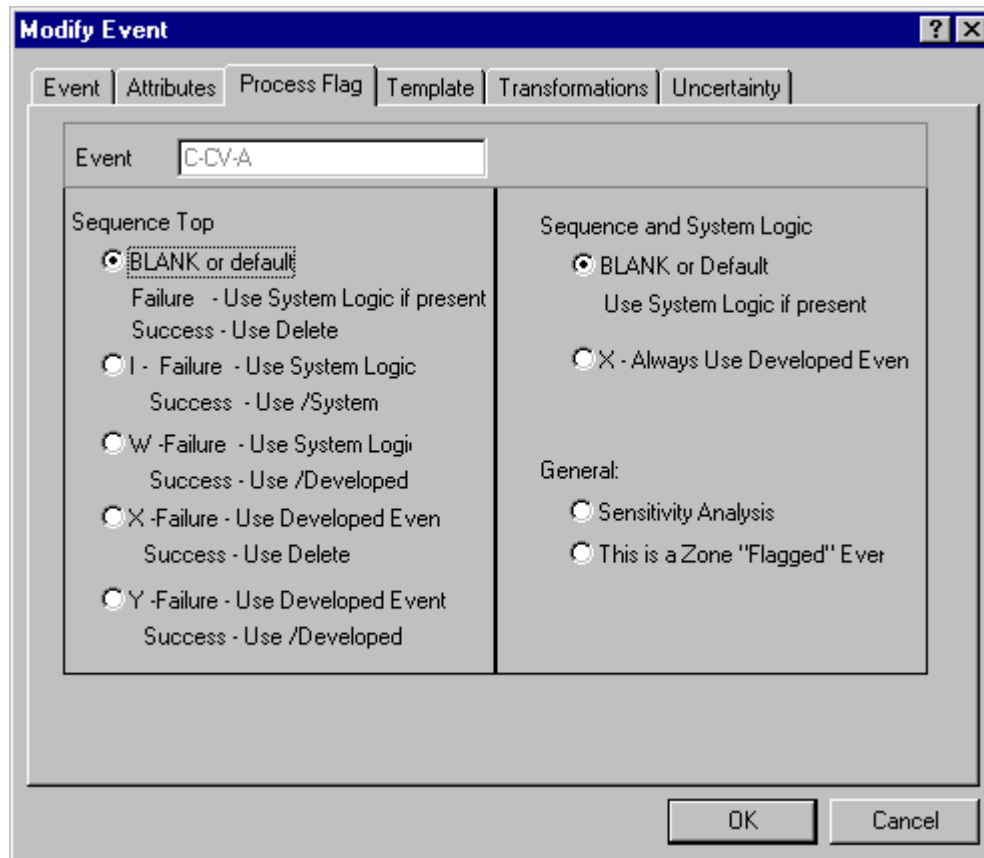
General purpose event - This is the default and is appropriate for most basic events.

'I' - Initiating event - Any initiating events should be identified with this category designation. The event tree editor will automatically enter an 'I' when the user specifies that the first event is an initiating event.

'H' - Hazard event - This is a special calculation type assigned to histogram bins for hazard analysis.

'R' - Recovery event - Events with this category designation will be listed in a list of recovery events used in the Recovery Rules editor

6.1.3 Basic Event Process Flags



Blank or Default

When the Process Flag field is blank, the transfer associated with this event is expanded for failure references. For success references, the transfer is also expanded; however, the cut sets generated are removed from the failure cut sets using cut set matching.

Process Flag 'I'

Use system logic (if top event fails), use the complement of the system logic (if top event succeeds). That is, if the top event is a failure, SAPHIRE will expand the fault tree and solve; if the event succeeds, SAPHIRE will complement the fault tree logic and solve it. An "I" causes SAPHIRE to treat the transfer as independent. Logic below this transfer is expanded for failure references, and for success references the complement of the logic is used.

Process Flag 'W'

Use system logic (if top event fails), use complement of the developed event (if top event succeeds). That is, if the event fails SAPHIRE will expand the fault tree and solve; if the event succeeds, SAPHIRE will use the complement of the developed event for the system.

Process Flag 'X'

Use developed event (if event fails), use cut set matching to eliminate cut sets (if event succeeds). That is, an "X" tells SAPHIRE that the basic event is to be used for failure references, but success references are to be treated the same as if the flag was blank.

Process Flag 'Y'

Use developed event (if event fails), use complement of developed event (if event succeeds). That is, a "Y" indicates that a transfer is to be replaced with its basic event for failed references and the complement of the event is to be used for success references.

Process Flag 'X'

Always use developed event. That is, never expand the fault tree and solve; always use the event.

Sensitivity Analysis

If an event is marked for sensitivity analysis, SAPHIRE will map a core damage frequency plot. A sensitivity analysis allows you to see how sensitive the core damage frequency is in relation to an event.

Zoned Flagged Event

A zone flagged event is an event that has been marked as representing a zone (i.e., location or area). An example of a zone is a fire zone or a flood zone. When SAPHIRE encounters a zone flagged event, it performs a transformation. A transformation is an event or set of events that replace a zone flagged event.

6.1.4 Basic Event Template

The screenshot shows the 'Modify Event' dialog box with the 'Template' tab selected. The 'Event' field contains 'C-CV-A'. The 'Template Event?' checkbox is checked, and the 'Template' dropdown menu is open, showing a list of event names. The 'Attributes' section contains checkboxes for Component Id., Process Flag, Category, System, Train, Type, Failure Mode, and Location. The 'Random Failure' section contains checkboxes for CalculationType, Probability, Lambda, Tau, and Mission Time. The 'Uncertainty' section contains checkboxes for DistributionType, Uncertainty Value 1, Uncertainty Value 2, and Correlation Class. The 'Other' section contains checkboxes for Description, Susceptibilities, and Transformations. The 'OK' and 'Cancel' buttons are at the bottom right.

Template Name

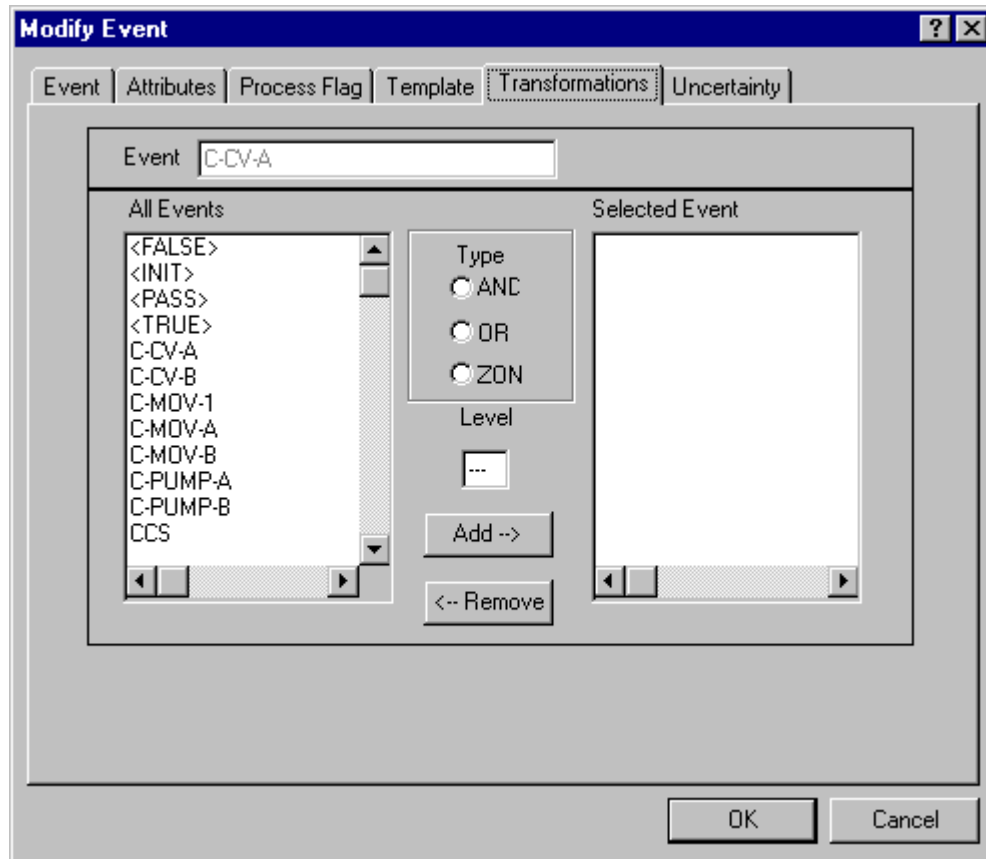
If you wish to use another event's information as a template for this basic event, select the name of the event from the drop-down list. Then check the box next to the desired characteristics to be used by this basic event. By default, all of the template event characteristics are selected.

Template Event

Select this check box if you wish to use the basic event as a template for other basic events in the database.

6.1.5 Basic Event Transformations

Select basic event(s) from the *All Events* list and the desired **Type** and **Level**.



Transformation - Type

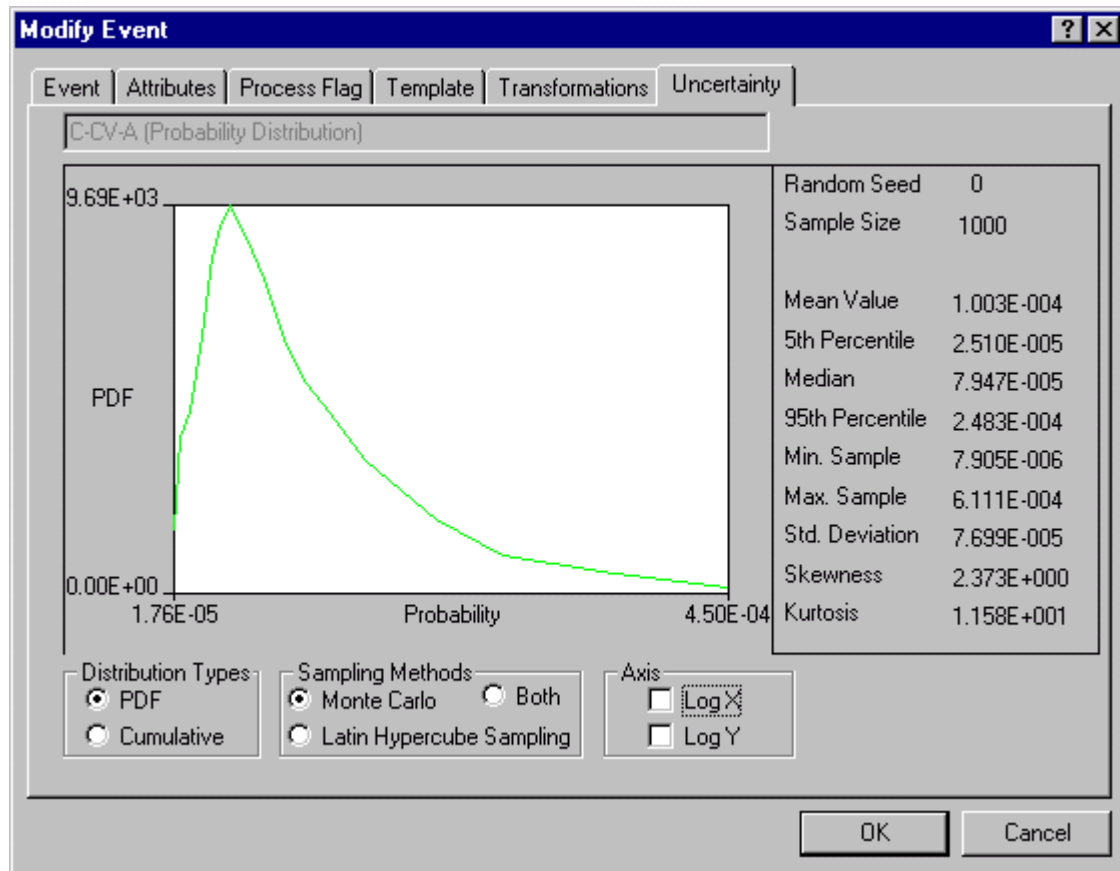
This field indicates the required behavior of the collective events. Enter one of the following:

- AND** = All included events must fail. Event is replaced with an AND gate, with all marked events as inputs.
- OR** = Any included events must fail. Event is replaced with an OR gate with all marked events as inputs.
- ZOR** = Events make up the zone. If any events in the list fail, all events fail.

Transformation - Level

Enter an integer between 0 and 255 indicating the level of substitution for the transformation.

6.1.6 Basic Event Uncertainty



Monte Carlo Sampling (MCS)

Simple MCS is a fundamental uncertainty sampling approach. To perform the sampling, SAPHIRE makes repeated quantifications of the system/sequence/end state cutsets using samples from the basic event uncertainty distributions. This type of sampling requires more samples than LHS for the same degree of accuracy.

When using this sampling technique, if the number of samples entered is less than ten, then the number of samples will be increased to ten before the uncertainty analysis process will continue. Any number of samples greater than or equal to ten will be allowed, but a number of at least 1000 is probably a better value for improving the reliability of the Monte Carlo results.

Latin Hypercube Sampling (LHS)

LHS is a stratified sampling technique where the random variable distributions are divided into equal probability intervals. A probability is randomly selected from within each interval for each

basic event. Generally, LHS will require fewer samples than simple MCS for similar accuracy. However, due to the stratification method, it may take longer to generate a value than for a MCS.

When using this technique, if the number of samples entered is less than twice the total number of unique events in the system/sequence/end state, then the number of samples will be increased to two times the total number of unique events before the analysis will continue. The LHS technique gives its best results if the number of samples is at least twice the total number of unique events.

6.2 Terms You Should Know

Developed Event

An event in SAPHIRE that is either an event tree top or a fault tree gate. Regular fault tree basic event *are not* considered developed events.

Delete Term

In SAPHIRE, the process known as "delete term" refers to the removal of sequence success cut sets from the list of failure cut sets when generating sequence cut sets. As an example of the "delete term", consider a sequence where top event A is successful and top event B is failed. Any cut sets that would fail A should not be allowed in the cut sets for B, so those cut sets are removed from the sequence.

6.3 Using Generate Event Data to Process Event Data

- ◆ Use the **Modify → Basic Events** menu to enter basic event data.
- ◆ Close the basic events dialogs.
- ◆ Select **Generate** from the menu bar, and select the **Generate** button. To process the base case data, do not Mark any change sets.

7. GRAPHICAL OUTPUT

Section 7 describes the **Alpha to Graphics** conversion and **Page Tree** features for fault tree graphics, and how to print **fault tree** and **event tree** graphics.

7.1 The Fault Tree Alpha to Graphics Feature

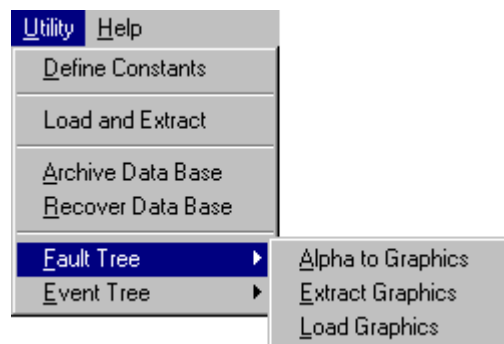
Function □ The □Alpha to Graphics□ feature uses internally stored fault tree logic to create a graphical fault tree file that can be viewed or edited in **Fault Tree** menu and printed from the **Report → Fault Tree → Graphic** menus.

◆ When to Use Alpha to Graphics

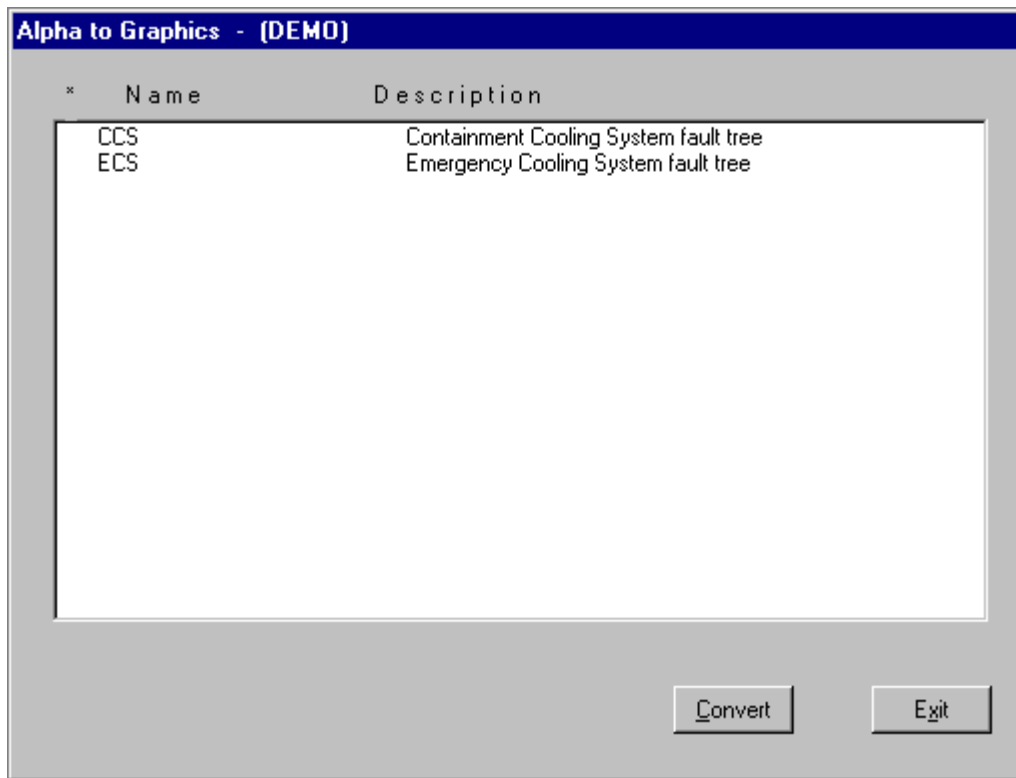
- ◇ To replace the fault tree graphic that you created in **Fault Tree → Edit Graphics** with a SAPHIRE-generated graphic that is evenly spaced and aligned or to use different basic event symbols.
- ◇ To update the existing fault tree graphic because you used the fault tree logic editor to modify fault tree logic.
- ◇ To create a fault tree graphic after loading the fault tree logic into the database via the MAR-D interface.

Using the Fault Tree Alpha-to-Graphics Feature

□ To use the Alpha to Graphics feature, select **Utility → Fault Tree**.

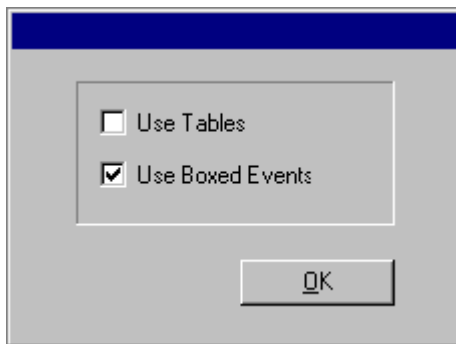


□ Choose the **Alpha to Graphics** sub-menu option.



- Highlight the desired system(s) and choose the **Convert** button.

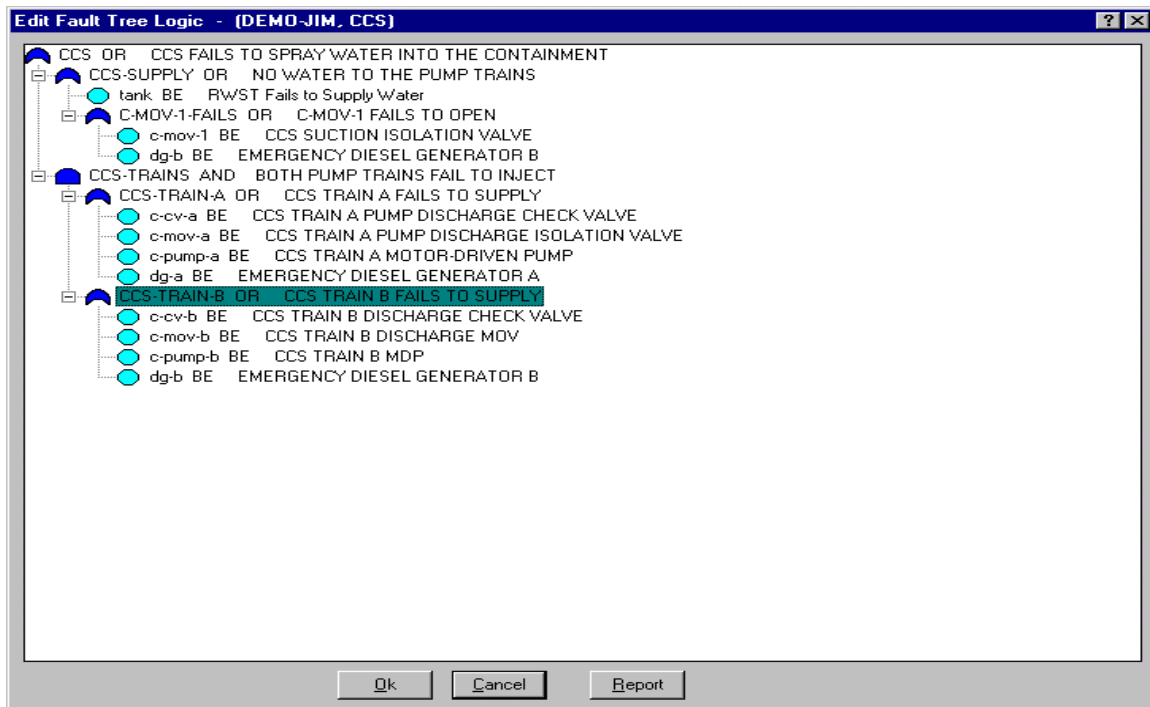
Specifying Alpha to Graphics Conversion Options



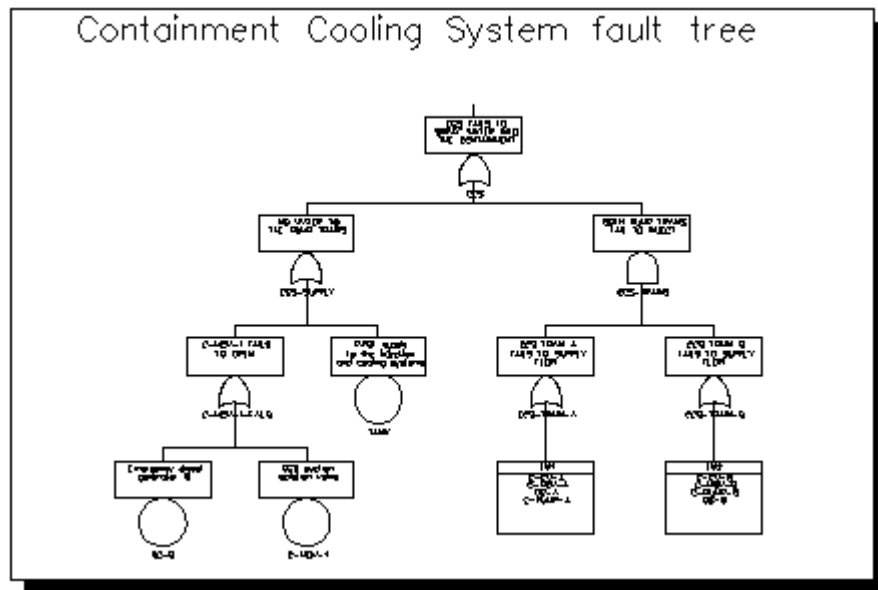
- To place basic events in the *Table of Basic Events* symbol, select the "Use Tables" check box.
- You may also choose from the two basic event symbols, the round *Basic Event* symbol or the *Boxed Basic Event* symbol. To use the *Boxed Basic Event* symbol, select the "Use Boxed Events" check box.

- Note: Special basic event symbols such as the Undeveloped Event symbol are not distinguished from ordinary basic events in the fault tree logic; therefore, the Alpha to Graphics conversion will *only* use the boxed, unboxed, or table basic event symbols.

Example of Alpha to Graphics Conversion



Alpha to Graphics Conversion



- ◆ After performing the Alpha to Graphics conversion, the fault tree logic is converted to a graphical fault tree. The conversion was performed using Tables and Boxed Basic Events.
- ◆ Gate and basic event descriptions will automatically be placed on the fault tree.

7.2 The Page Tree Feature

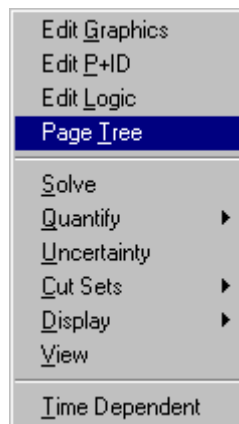
Function □ The **Page Tree** option is used to permanently divide one fault tree "page" or file into several "pages" or files. This allows you to divide the contents of a fault tree file so that it fits onto a printed page. Dividing the fault tree is accomplished by picking gates to be changed into transfers. Additionally, you can break out a subtree at a user-specified gate, output gates with multiple references to a separate subtree, or output multiple top gates into separate fault trees.

When Using the **Page Tree** Feature □

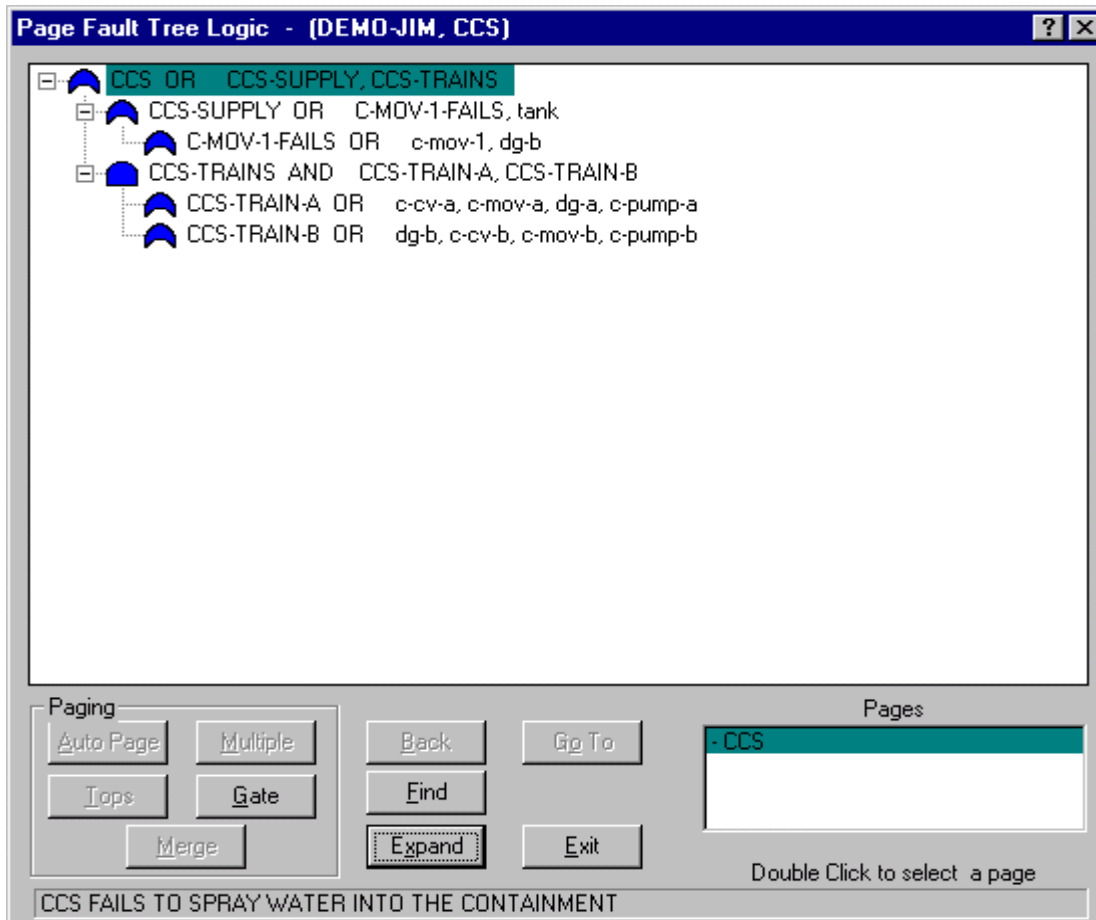
- ◆ It is a good idea to save a copy of the tree to be paged since "unpaging" the tree will require manual intervention.

Using the Page Tree Feature

- To use the Page Tree feature, select the **Fault Tree** option from the menu bar.
- Highlight the fault tree to be paged and right-click to invoke the pop-up menu.
- Select the **Page Tree** option.



- The *Page Fault Tree Logic* dialog is displayed.



Page Options

Multiple - Break out gates with multiple references (i.e., gates that appear in more than one location within the fault tree) and output the logic into separate subtrees. Enabled only when multiply-referenced gates are detected.

Tops - Automatically separate the logic file into different fault trees by the top events. Enabled only when multiple tops in the logic are detected.

Gate - Create a separate fault tree logic file with the specified gate as the top event.

Find - Locate a specified gate.

Go To - Follow a transfer to another fault tree file.

Merge - Merge the logic represented by a transfer gate into the current fault tree file. This will occur only if the gate is not referenced more than once within the fault tree.

Auto Page - Automatically break the fault tree into easily viewable segments

Expand - Expand all gates in the current fault tree file.

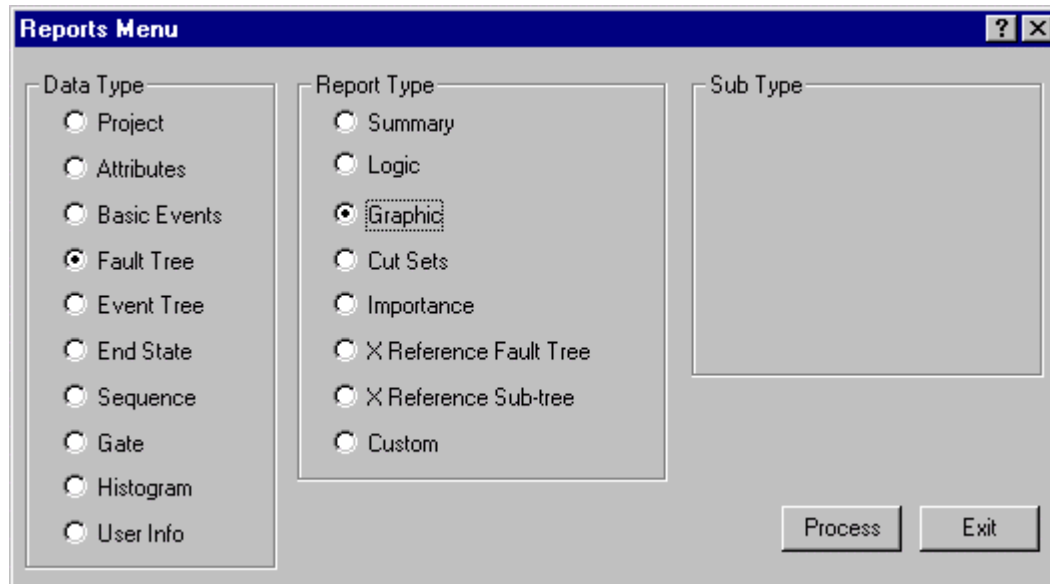
Back - Reload the previous fault tree file. This option is enabled only after executing the **Go To** option.

Pages - List of existing pages. Double-click on a page in the list to make it the current page.

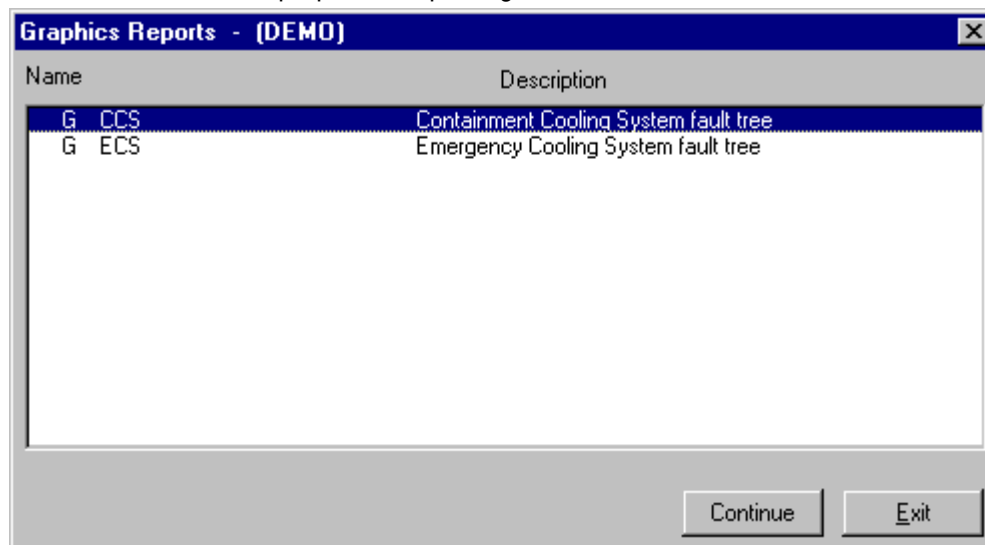
Exit - Close the *Page System Logic* dialog. If changes were made to the system logic, you will be prompted to save the changes before exiting.

7.3 Printing Fault Tree Graphics

□ To print fault tree graphics, select **Report → Fault Tree → Graphic**.



□ Select the files to be prepared for plotting, and choose the **Continue** button.

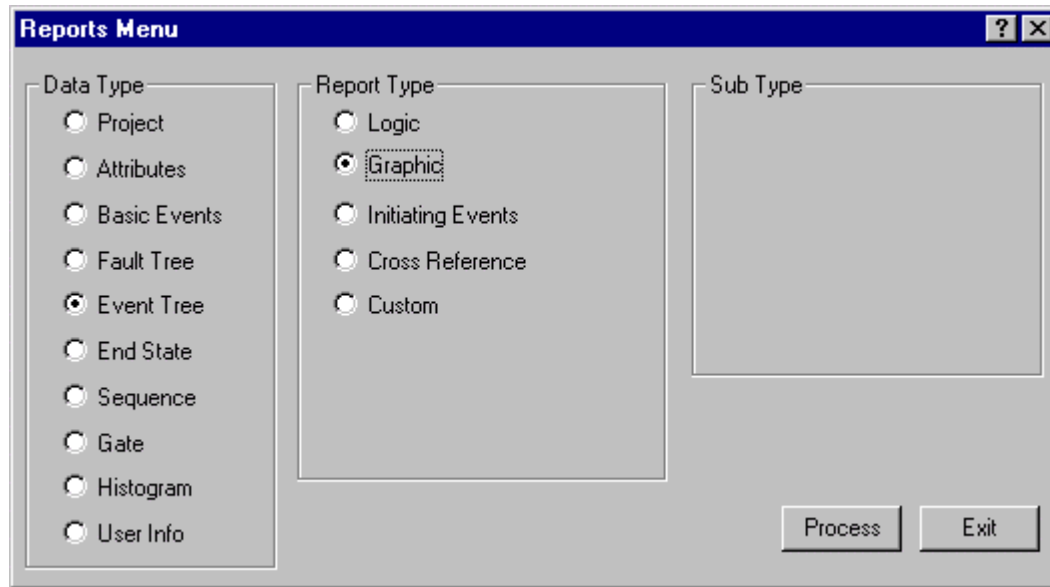


The *Fault Tree Printer* window will be displayed along with the *Print* dialog.

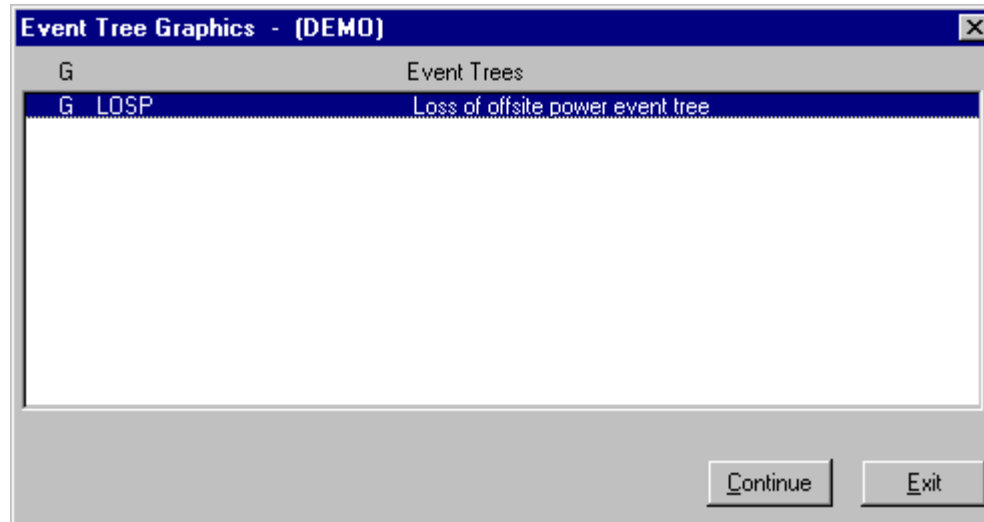
◇ Note: the size and alignment of the graphic as it appears in the graphical editor prior to using the print option dictates the appearance of the printed graphic.

7.4 Printing Event Tree Graphics

□ To print event tree graphics, select **Report → Event Tree → Graphic**.



□ Select the files to be prepared for plotting, and choose the **Continue** button.

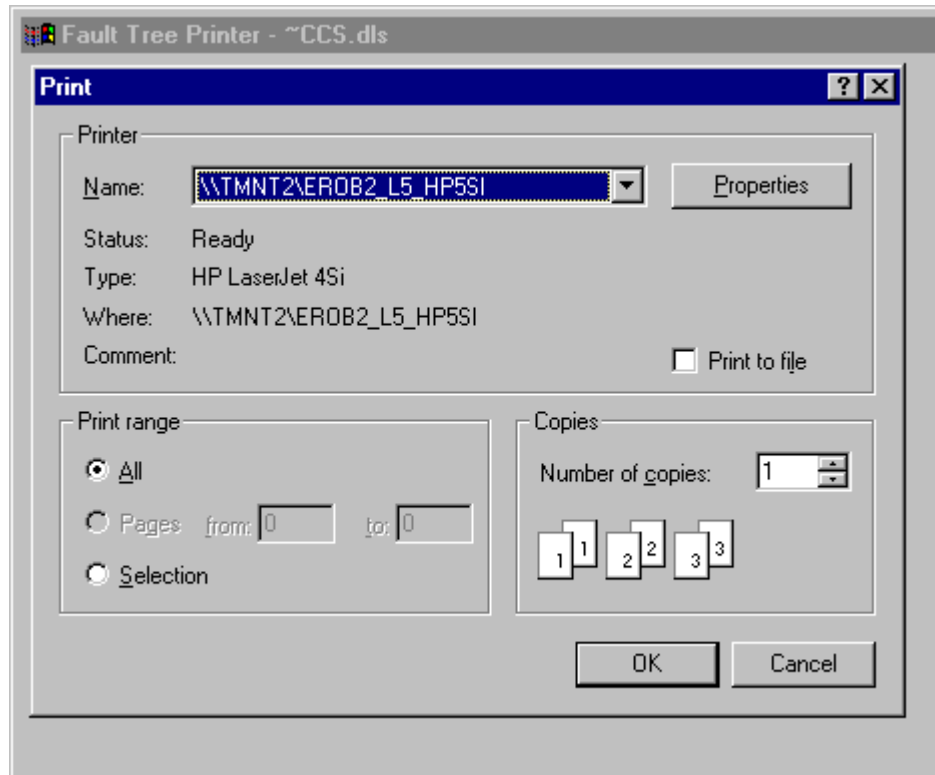


The *Event Tree Printer* window will be displayed along with the *Print* dialog.

◇ Note: the size and alignment of the graphic as it appears in the graphical editor prior to using the plot option dictates the appearance of the printed graphic.

Fault Tree Printer

- This window is displayed when printing event tree or fault tree graphics files.



OK - Print the graphic file(s) to the designated printer.

Cancel - Close the *Print* dialog along with the *Fault Tree Printer* window.

8. GENERATING SYSTEM CUT SETS

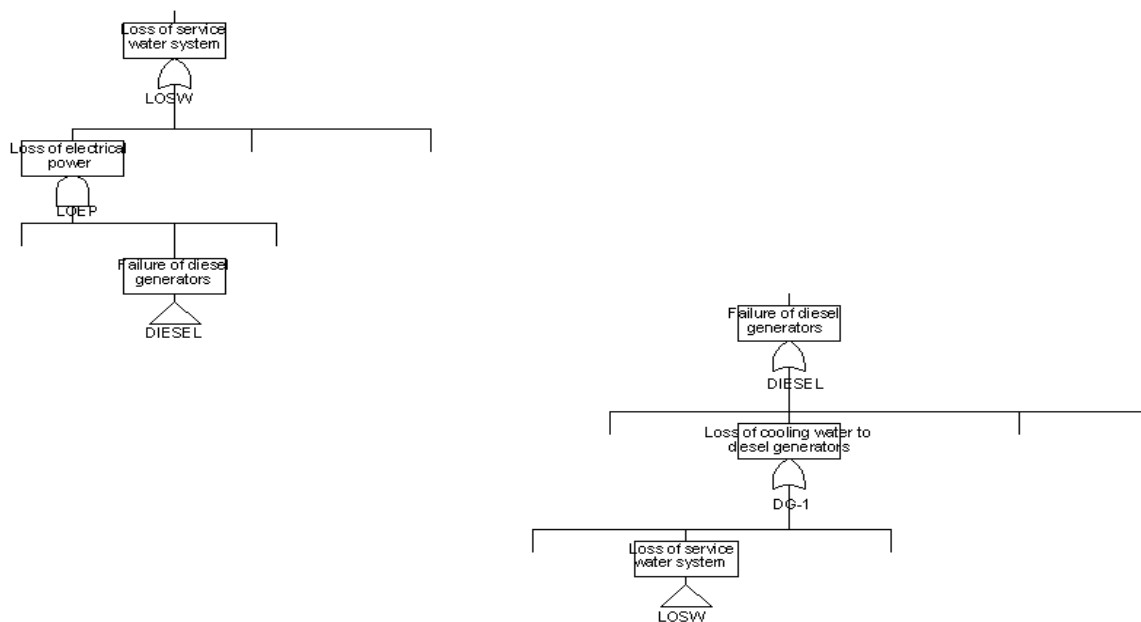
Section 8 describes how to generate system (i.e., fault tree) cut sets. **Model preparation** prior to generating cut sets is discussed, and the various **analysis and truncation options** are described. **Cut set display** features are also presented.

- ◆ Indicate several prerequisites for generating system cut sets.
- ◆ Generate system cut sets.
- ◆ View generated system cut set results.

8.1 Prerequisites for Generating System Cut Sets

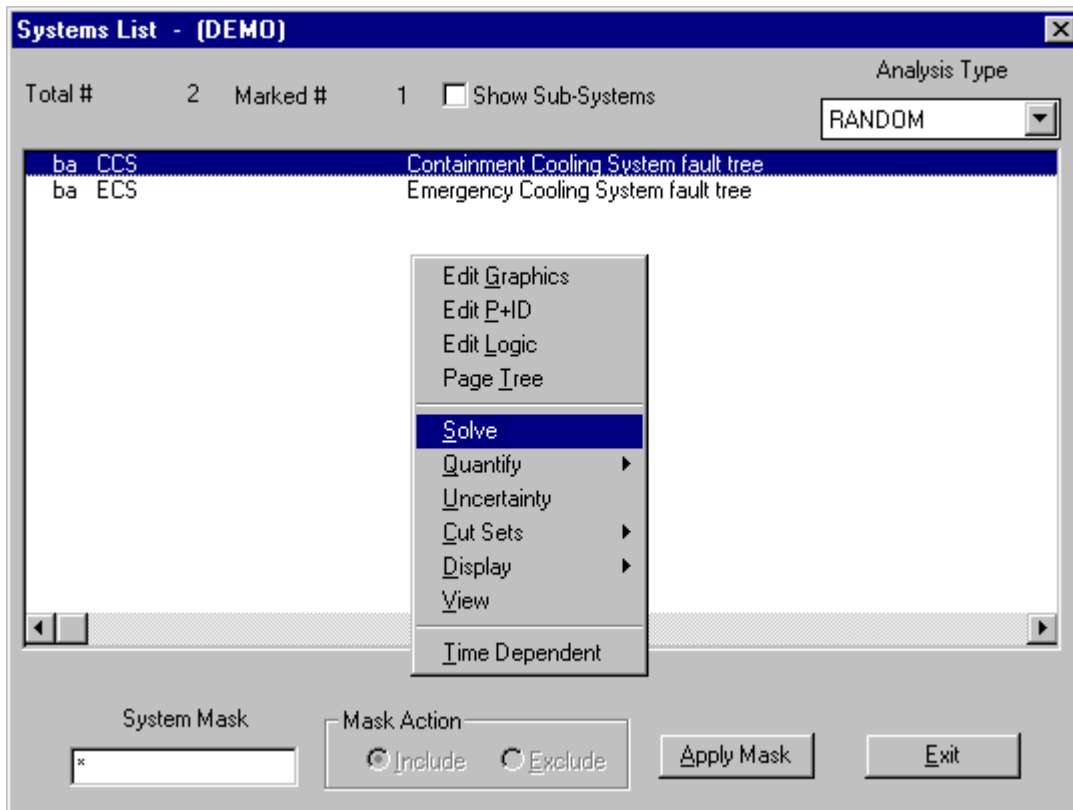
- ① Fault tree logic was created by using the fault tree graphics editor, fault tree logic editor, or loaded into the database via the MAR-D interface.
- ② Basic event data were added through the **Modify → Basic Events** menu.
- ③ Basic event data was prepared for model processing by using the **Generate** option.
- ④ Fault tree transfers are properly modeled so that
 - ◇ There are no **logic loops** in the fault trees
 - ◇ There is only one top gate in each fault tree
 - ◇ The naming of transfer gates and fault tree filenames is consistent.

Logic Loop Example



The correct way to "break the loop" will depend on which system is being analyzed.

8.2 Menus and options for system cut set generation



- Select the **Fault Tree** option from the menu.
- Mark the Fault Trees using the mask feature, or using the mouse.
- Right-click to invoke the pop-up menu.
- Select the **Solve** option.
-

In the left-hand column...

b - flags systems with base case cut sets

a - flags systems with alternate case cut sets

This option uses the fault tree logic from all fault trees that link to the top gate in the system. The system probability is quantified using the minimal cut set upper bound approximation.

Truncation Parameters

Cut Set Generation

☒ Cutoff by Cut Set Probability ☐ Fault Tree ☒ Global < Global Cutoff Value 1.000E-008

Cutoff by Event Probability ☐ Min < Cutoff Value -----E-----

Cutoff by ☐ Size ☐ Zone ☒ None > Cutoff Value 6

Starting Gate Name Flag Set Name

Auto Apply Recovery Rules ☐

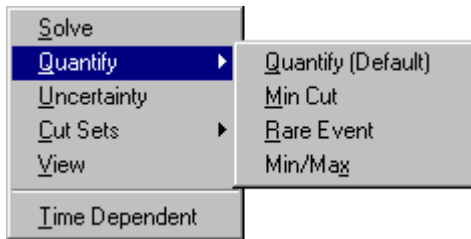
NOTE: To perform Event Probability truncation you must also specify CutSet Probability truncation and the associated cutoff value.

OK Cancel

- Select the desired truncation parameters on the dialog, and choose **OK** to begin generating cut sets.

- ▶ **Cutoff by Cut Set Probability** - If you select this check box, then those cut sets below the cutoff value will not be retained. Choose one of the radio buttons:
 - Global** - Only those cut sets whose product for all of its event probabilities is greater than or equal to the value in the < **Global Cutoff Value** field will be kept.
 - Fault Tree** - Only those cut sets whose product for all of its event probabilities is greater than or equal to the fault tree's cutoff value will be kept. This value is entered in the **Modify** → **Fault Tree** option.
- ▶ **Cutoff by Event Probability** - If you select this check box, then you must also select the **Cutoff by Cut Set Probability** check box. This option will retain cut sets comprised of basic events that are above the **Min < Cutoff Value** even if the cut set is below the **Global Cutoff Value**.
- ▶ **Cut Set Size** - If you select this check box, then cut sets having more events than specified in the > **Cutoff Value** field will not be retained. If you select the **Zone** check box, then cut sets having more Zone Flagged Events than specified in the > **Cutoff Value** field will not be retained. If neither check box is selected, then the number of events in a cut set will not affect whether the cut set is retained or discarded.
- ▶ **Starting Gate Name** - If you leave the field blank, the top gate in the system will be used. If you specify a gate, that gate will be used as though it were the top gate.
- ▶ **Flag Set Name** - If you leave the field blank, the system-specific flag set, if any, will be used. If you specify a flag set, that flag set will be used during processing.
- ▶ **Auto Apply Recovery Rules** – If you check box, any recovery rules associated with this fault tree will automatically be applied after the fault tree cut sets have been generated.

Quantify



This submenu provides options for requantifying existing current case system cut sets. These options are designed to quickly requantify the cut sets when data changes have been made. (Note: if data changes increase the failure probability of an event, the Solve option should be used instead.)

Minimal Cut Set Upper Bound Approximation

This calculation approximates the probability of the union of the minimal cut sets for the fault trees. The equation for the minimal cut set upper bound is

$$S = 1 - \prod_{i=1}^m (1 - C_i)$$

where

S = minimal cut set upper bound for the system unavailability,

C_i = probability of the ith cut set, and

m = the number of cut sets.

Example: If the cut sets for a system are $X = A \cup B \cup C$ (i.e., the union of three events, A, B, and C); then the cut sets can be written as $X = A + B + C$ with the plus symbol indicating union. The system unavailability computed from the minimal cut set upper bound approximation is then $X = 1 - (1 - A)(1 - B)(1 - C)$.

Min Max Quantification

The Min-Max quantification option quantifies the current case cut sets using the exact probability quantification algorithm. From the example above, the exact system unavailability is

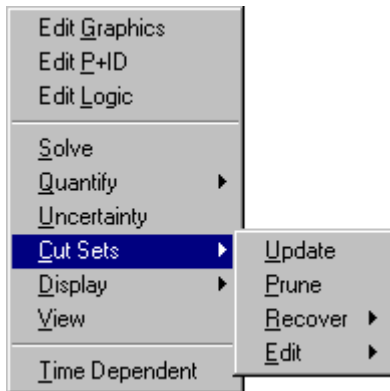
$$X = (A + B + C) - (A * B + A * C + B * C) + (A * B * C),$$

with the number of passes in this example being 3, corresponding to the number of pairs of parentheses.

Uncertainty

Performs Monte Carlo or Latin Hypercube uncertainty analysis for the selected system. System uncertainty analysis is discussed further in Section 9.

Cut Set Analysis



This sub-menu provides options for cut set manipulation.

Cut Set Update

This option uses the existing current case cut sets (unless the user specifies that base case cut sets are to be used instead). Non-minimal cut sets are eliminated and the system probability is quantified using the minimal cut set upper bound approximation.

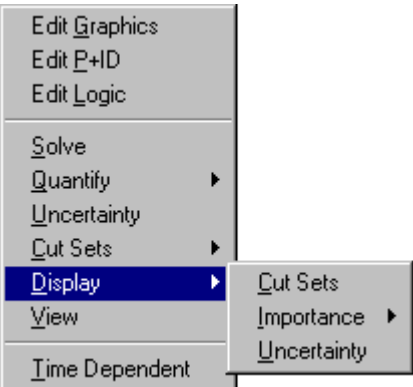
Prune Cut Sets

This is one of the options that allows you to eliminate cut sets from a selected system that contains events which conflict in some way with one another. The prune cut set option has been superseded by the "Cut Set, Recovery" option.

Analysis Type

Select the RANDOM analysis type for material covered in this class. The other analysis types are provided for performing fire, flood, seismic, and other hazard analyses.

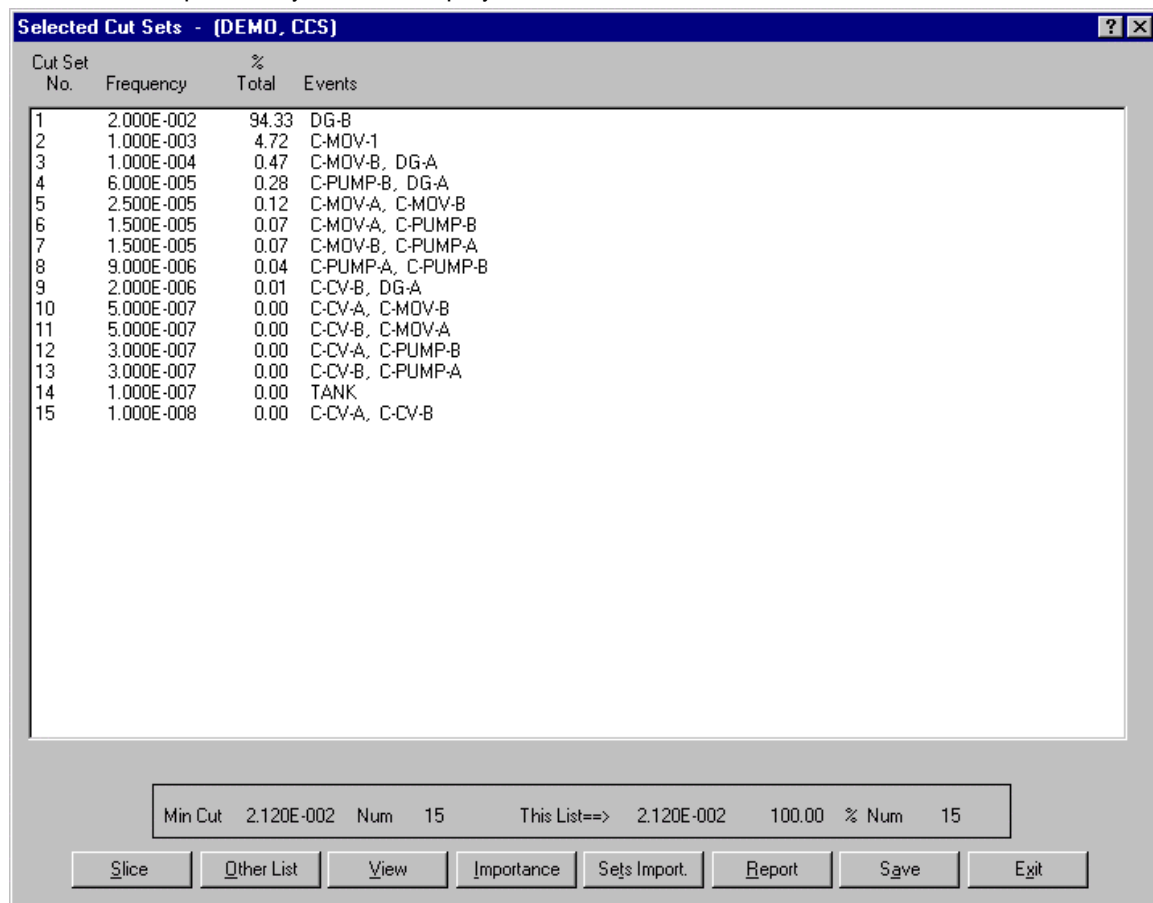
Displaying System Cut Set Results



- To display system cut sets, select **System** from the menu bar.
- Highlight the system that you want to view; right-click to invoke the pop-up menu.
- Select the **Display** → **Cut Sets** option.

Selecting System Cut Sets to View

- The system cut sets and minimal cut set upper bound approximation of the system failure probability are now displayed.



Cut Set No.	Frequency	% Total	Events
1	2.000E-002	94.33	DG-B
2	1.000E-003	4.72	C-MOV-1
3	1.000E-004	0.47	C-MOV-B, DG-A
4	6.000E-005	0.28	C-PUMP-B, DG-A
5	2.500E-005	0.12	C-MOV-A, C-MOV-B
6	1.500E-005	0.07	C-MOV-A, C-PUMP-B
7	1.500E-005	0.07	C-MOV-B, C-PUMP-A
8	9.000E-006	0.04	C-PUMP-A, C-PUMP-B
9	2.000E-006	0.01	C-CV-B, DG-A
10	5.000E-007	0.00	C-CV-A, C-MOV-B
11	5.000E-007	0.00	C-CV-B, C-MOV-A
12	3.000E-007	0.00	C-CV-A, C-PUMP-B
13	3.000E-007	0.00	C-CV-B, C-PUMP-A
14	1.000E-007	0.00	TANK
15	1.000E-008	0.00	C-CV-A, C-CV-B

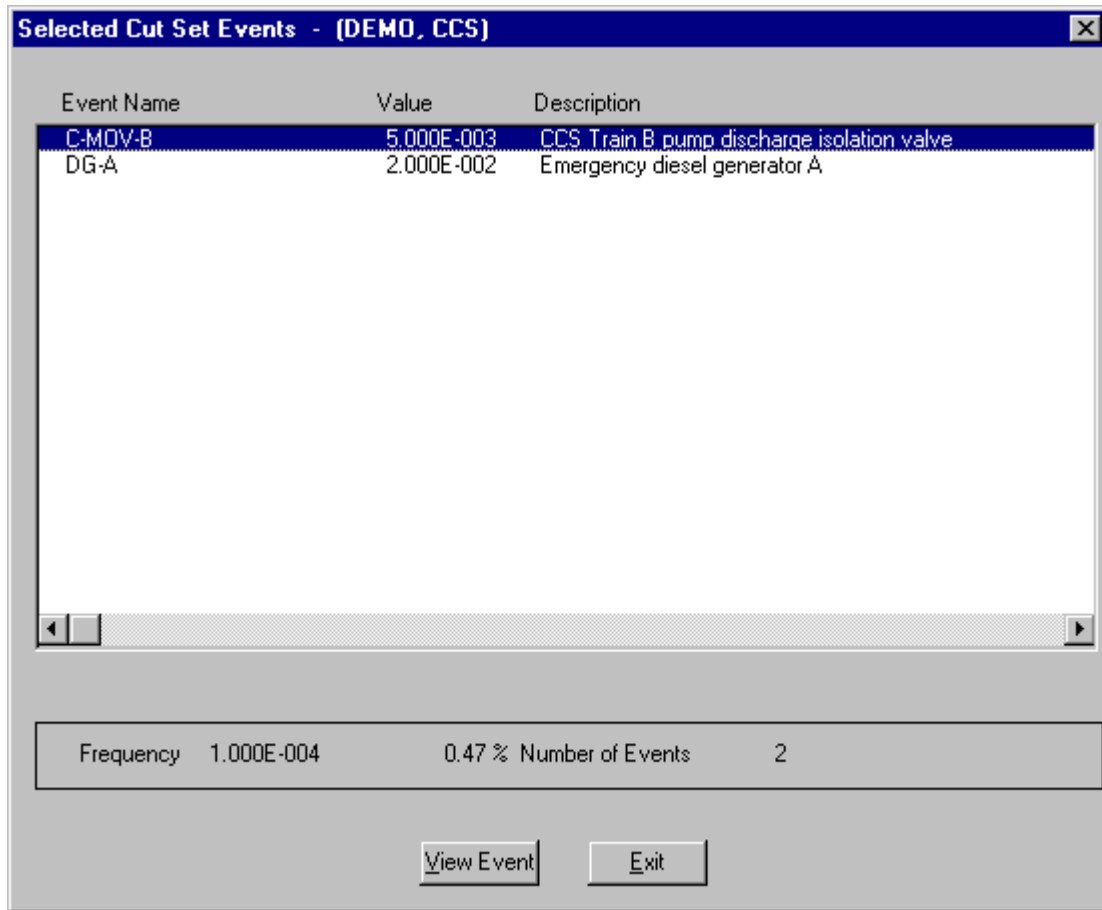
Min Cut: 2.120E-002 Num: 15 This List==> 2.120E-002 100.00 % Num: 15

Buttons: Slice, Other List, View, Importance, Sets Import, Report, Save, Exit

- To view the basic events in a cut set, highlight the cut set, choose the **View Cut Set** button.

Viewing System Cut Sets

- The basic events, their failure probabilities and descriptions are now displayed.



Event Name	Value	Description
C-MOV-B	5.000E-003	CCS Train B pump discharge isolation valve
DG-A	2.000E-002	Emergency diesel generator A

Frequency 1.000E-004 0.47 % Number of Events 2

[View Event](#) [Exit](#)

- To view individual basic event information, highlight the basic event, and choose the **View Event** button.
- To find out where the events in the cut set came from, right-click on a cut set and select the **Path Search** option.

The Path Search option traces through the fault tree logic to indicate exactly where in the logic did the cut set come from.

Viewing Basic Event Information for an Individual Cut Set

View Event [?] [X]

Family: DEMO

Event Names		Event Attributes			
Primary	C-MOV-B	Comp Id	C-MOV-	System	CC
Alternate	C-MOV-B	Process Flag	<input type="checkbox"/>	Train	<input type="checkbox"/>
		Category	<input type="checkbox"/>	Type	MO
				Fail Mode	A2
				Location	FZ2

Description: CCS Train B pump discharge isolation valve

Random Failure Data		Uncertainty Data	
Calculation Type	1	Distribution Type	L
Mean Failure Probability	5.000E-003	Name	Log Normal
Lambda	+0.000E+000	Error Factor	5.000E+000
Tau	+0.000E+000		-----E-----
Mission Time	+0.000E+000	Correlation Class	2
Current Probability	5.000E-003	Current Uncertainty	+0.000E+000

Susceptibilities																Transformations	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Type	Level
<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="text"/>	---

Exit

□ The individual basic event information is now displayed.

9. SYSTEM UNCERTAINTY ANALYSIS

Section 9 describes **uncertainty analysis** for systems. The concept of performing uncertainty analysis via Monte Carlo or Latin Hypercube sampling is discussed.

- ◆ Explain the two types of uncertainty analysis techniques available in SAPHIRE.
- ◆ List the different uncertainty distributions supported by SAPHIRE.
- ◆ Perform system uncertainty analysis.
- ◆ Display system uncertainty analysis results.

9.1 System Uncertainty Analysis

- ◆ Uncertainty analysis calculates the variability of a system top event probability resulting from uncertainties in the basic event probabilities.
- ◆ SAPHIRE provides two uncertainty analysis techniques:
 - ◇ **Simple Monte Carlo sampling**
 - ◇ **Latin Hypercube sampling**

Simple Monte Carlo Sampling

- ▶ A fundamental approach.
- ▶ Makes repeated quantifications of the system cutsets using each random variable sampled from the basic event uncertainty distributions.
- ▶ Requires more samples than Latin Hypercube sampling for the same degree of accuracy.

Latin Hypercube Sampling

- ▶ A stratified sampling technique, with the random variable distributions divided into equal probability intervals.
- ▶ Probability randomly selected from within each interval.
- ▶ May require fewer samples than simple Monte Carlo for similar accuracy; however, it may take longer to generate a random value than for a simple Monte Carlo sample.

9.2 Uncertainty Distributions for Basic Events

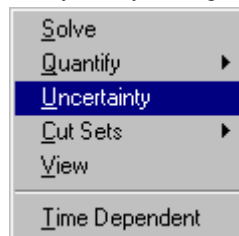
- ◆ Basic event distribution types supported by SAPHIRE:

Distribution	Code	Parameter
Blank		(Use point estimate value only)
Lognormal	L	error factor
Normal	N	standard deviation
Beta	B	b in Beta(a, b)
Dirichlet	D	
Gamma	G	r in $\Gamma(r)$
Chi-squared	C	degrees of freedom
Exponential	E	(none)
Uniform	U	upper end point
Histograms	H	histogram number
Max. Entropy	M	lower and upper end point
Seismic	S	Beta r, Beta u
Constrained Noninformative	O	

- ◆ Correlation classes may be specified by the user to identify data (or other) dependencies for basic events using data derived from the same data source.

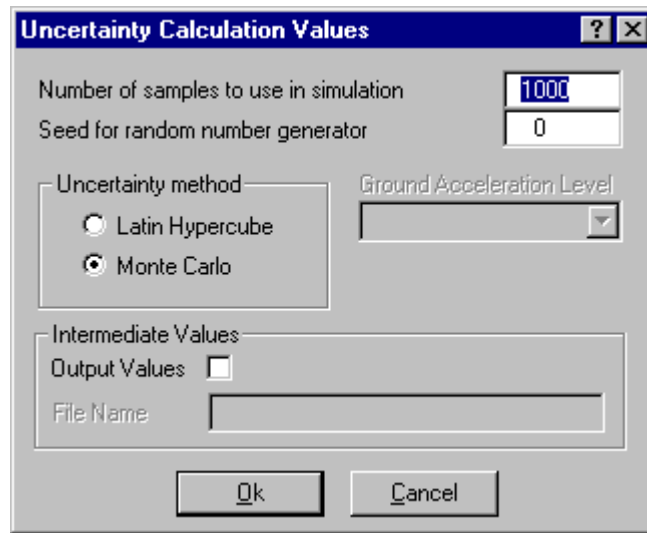
9.3 Menus and Options for Performing System Uncertainty Analysis

- Select **Fault Tree** from the menu bar.
- Mark the fault tree(s) for uncertainty analysis, right-click to invoke the pop-up menu.



- Select the **Uncertainty** option. The fault tree uncertainty will be calculated for each fault tree marked.

Uncertainty Calculation Values



Uncertainty Calculation Values

Number of samples to use in simulation: 1000

Seed for random number generator: 0

Uncertainty method:

- ☐ Latin Hypercube
- ☒ Monte Carlo

Ground Acceleration Level: [Dropdown]

Intermediate Values:

Output Values: ☒

File Name: [Text Box]

Ok Cancel

□ Enter the uncertainty calculation values on the screen:

- ▶ Select one of the uncertainty method radio buttons, Monte Carlo or Latin Hypercube.
- ▶ Input the number of samples. (A larger number of samples will provide more accurate results but will require more computation time.)
- ▶ Enter a value for the random number generator seed or accept the default. Enter zero to obtain a random seed from the system clock.
- ▶ Enter a Ground Acceleration Level if seismic uncertainty is selected.
- ▶ OPTIONAL: To save intermediate sample results to a disk file for review, select the Output Values check box and provide the Output file name. Note that the resulting text file may be quite large.

Uncertainty Results

Uncertainty Results			
Name	CCS		
Random Seed	41877	Events	10
Sample Size	1000	Cut Sets	15
Point estimate	2.120E-002		
Mean Value	2.047E-002		
5th Percentile Value	1.524E-003		
Median Value	8.788E-003		
95th Percentile Value	6.852E-002		
Minimum Sample Value	2.150E-004		
Maximum Sample Value	6.591E-001		
Standard Deviation	4.138E-002		
Skewness	7.312E+000		
Kurtosis	8.155E+001		
Elapsed Time	00:00:00.690		
<input type="button" value="Cancel"/>			

- Uncertainty results will be displayed briefly on the screen following the uncertainty calculation.
- Uncertainty results for each system can also be displayed from the **System → Display → Uncertainty** menu.

System Uncertainty - (DEMO, CCS)					
Base					
Mear	2.111E-002	Median	8.797E-003	Mincut	2.120E-002
Std. Dev	4.420E-002	Skewness	8.129E+000	Kurtosis	+0.000E+000
5th %	1.452E-003	Minimum	3.483E-004	Seec	7550
95th %	7.723E-002	Maximum	7.526E-001	Samples	1000
Size Cutoff		--	Probability Cutoff		1.000E-015
Current					
Mear	2.272E-002	Median	8.659E-003	Mincut	2.120E-002
Std. Dev	4.982E-002	Skewness	7.893E+000	Kurtosis	1.000E+000
5th %	1.540E-003	Minimum	3.206E-004	Seec	23697
95th %	8.566E-002	Maximum	8.621E-001	Samples	1000
Size Cutoff		--	Probability Cutoff		1.000E-015
<input type="button" value="Current Quantile Values"/>		<input type="button" value="Base Quantile Values"/>		<input type="button" value="Exit"/>	

10. SYSTEM IMPORTANCE ANALYSIS

Section 10 describes the various system **importance measures** available in SAPHIRE. Also, how to **calculate the importance measures** using SAPHIRE is shown.

- ◆ Explain the use and meaning of importance measures.
- ◆ Define the importance measures that are available in SAPHIRE for systems (fault trees).
- ◆ Discuss the steps used to calculate system importance measures.
- ◆ View ratio importance measure results.
- ◆ View difference importance measure results

10.1 System Importance Measures

- ◆ Importance measures provide "reliability-worth" information about basic events appearing in the cut sets for a fault tree.
- ◆ Components showing high relative importance may be candidates for either (1) close monitoring to ensure that the component does not degrade over time or (2) design changes to increase the component reliability.
- ◆ *Ratio, Difference or Uncertainty* importances can be selected.
 - ◇ When you select *Ratio Importances* " **Fussell-Vesely Importance**, **Risk Reduction Ratio**, and **Risk Increase Ratio** will be calculated, displayed, and reported.
 - ◇ When you select *Difference Importances* " **Birnbaum Importance**, **Risk Reduction Interval**, **Risk Increase Interval** will be calculated, displayed, and reported.

10.2 Definitions of the Importance Measures

Fussell-Vesely Importance (FV)

An indication of the fractional contribution of the basic event to the minimal cut set upper bound.
The equation for FV importance is

$$FV = [F(x) - F(0)]/F(x)$$

where

$F(x)$ is the original minimal cut set upper bound

$F(0)$ is the minimal cut set upper bound with the event probability set equal to 0.0.

Risk Reduction Ratio (RRR) or Risk Reduction Interval (RRI)

An indication of how much the minimal cut set upper bound would decrease if the basic event probability was reduced (to a probability of 0.0).

$$RRR = F(x)/F(0)$$

$$RRI = F(x) - F(0)$$

(Note the similarity between RRI and FV; the relative importance ranking of basic events will be the same for the two importance measures.)

Risk Increase Ratio (RIR) or Risk Increase Interval (RII)

An indication of how much the minimal cut set upper bound would increase if the basic event probability was increased (to a probability of 1.0).

(Note: If the event probability is close to 1.0, this importance measure may yield a small RIR or RII.)

$$RIR = F(1)/F(x)$$

$$RII = F(1) - F(x)$$

where

$F(x)$ is the original minimal cut set upper bound

$F(1)$ is the minimal cut set upper bound with the event probability set equal to 1.0.

Birnbaum Importance (B)

Indicates the sensitivity of the minimal cut set upper bound with respect to a change in the basic event probability.

$$B = F(1) - F(0)$$

where

$F(1)$ is the minimal cut set upper bound with the event probability set equal to 1.0.

$F(0)$ is the minimal cut set upper bound with the event probability set equal to 0.0.

Some useful importance measures relationships:

- ◇ The Birnbaum importance is equal to the sum of the RII and RRI importances.

$$B = RII + RRI$$

- ◇ Fussell-Vesely (FV) importance is equal to the product of the Birnbaum importance and the event probability, divided by the minimal cut set upper bound.

$$FV = (B * x) / R(x)$$

- ◇ RRI importance is equal to the product of the Birnbaum importance and the nominal basic event probability (RRI importance is sometimes referred to as the [inspection importance]).

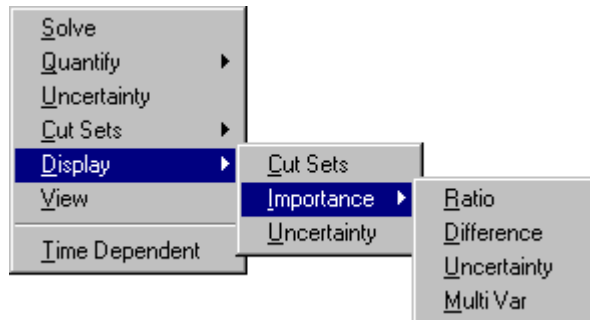
$$RRI = B * x$$

- ◇ RII importance is equal to the product of the Birnbaum importance and the complement of the basic event probability.

$$RII = B * (1 - x)$$

10.3 Importance Menus and Options

- Select **Fault Tree** from the menu bar.
- Highlight the fault tree, right-click to invoke the pop-up menu.



- Select **Importance**, then one of the sub-menu options. **Ratio** was selected in the following example.

Viewing Importance Measures

- The Ratio importance measures are now displayed.

The image shows a dialog box titled "Importance Measures - (DEMO, CCS)". It has a "Sort" dropdown menu set to "F-V". Below the menu is a table with the following data:

Event Name	# of Occur	Probability	F-V	Risk Reduc. Ratio	Risk Inccr. Ratio
DG-B	1	2.000E-002	9.418E-001	1.718E+001	4.715E+001
C-MOV-1	1	1.000E-003	4.619E-002	1.048E+000	4.715E+001
DG-A	3	2.000E-002	7.477E-003	1.008E+000	1.366E+000
C-MOV-B	4	5.000E-003	6.692E-003	1.007E+000	2.322E+000
C-PUMP-B	4	3.000E-003	4.015E-003	1.004E+000	2.325E+000
C-MOV-A	3	5.000E-003	1.869E-003	1.002E+000	1.371E+000
C-PUMP-A	3	3.000E-003	1.121E-003	1.001E+000	1.372E+000
C-CV-A	3	1.000E-003	3.738E-004	1.000E+000	1.373E+000
C-CV-B	4	1.000E-004	1.338E-004	1.000E+000	2.329E+000

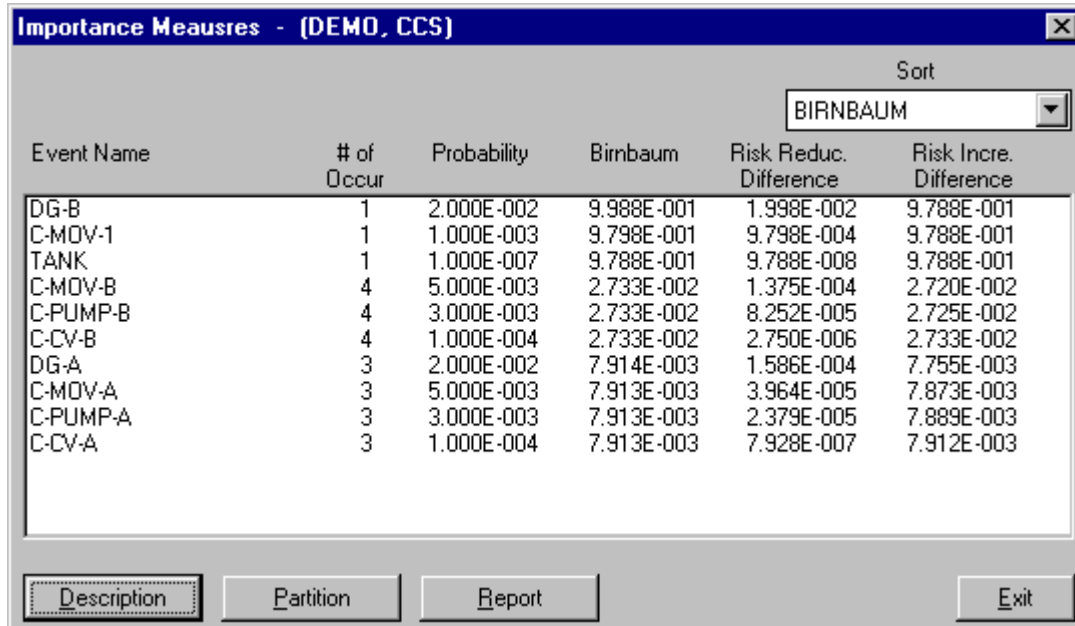
At the bottom of the dialog box are four buttons: Description, Partition, Report, and Exit.

- Use the Report button on this dialog to write the importance measure to a file or printer. (Note that *Ratio* importances are displayed.)
- Alternately, the **Report → Fault Tree → Importance** option can be used to report

system importances.

Displaying Difference Importances

- Now select the → **Display** → **Importance** → **Difference** option, difference importances are displayed.



The screenshot shows a software window titled "Importance Measures - (DEMO, CCS)". It features a table with six columns: "Event Name", "# of Occur", "Probability", "Birnbaum", "Risk Reduc. Difference", and "Risk Incre. Difference". The table is sorted by the "Birnbaum" column, as indicated by the "Sort" dropdown menu which is set to "BIRNBAUM". The table lists ten events: DG-B, C-MOV-1, TANK, C-MOV-B, C-PUMP-B, C-CV-B, DG-A, C-MOV-A, C-PUMP-A, and C-CV-A. Each event has associated numerical values for the other five columns. At the bottom of the window, there are four buttons: "Description", "Partition", "Report", and "Exit".

Event Name	# of Occur	Probability	Birnbaum	Risk Reduc. Difference	Risk Incre. Difference
DG-B	1	2.000E-002	9.988E-001	1.998E-002	9.788E-001
C-MOV-1	1	1.000E-003	9.798E-001	9.798E-004	9.788E-001
TANK	1	1.000E-007	9.788E-001	9.788E-008	9.788E-001
C-MOV-B	4	5.000E-003	2.733E-002	1.375E-004	2.720E-002
C-PUMP-B	4	3.000E-003	2.733E-002	8.252E-005	2.725E-002
C-CV-B	4	1.000E-004	2.733E-002	2.750E-006	2.733E-002
DG-A	3	2.000E-002	7.914E-003	1.586E-004	7.755E-003
C-MOV-A	3	5.000E-003	7.913E-003	3.964E-005	7.873E-003
C-PUMP-A	3	3.000E-003	7.913E-003	2.379E-005	7.889E-003
C-CV-A	3	1.000E-004	7.913E-003	7.928E-007	7.912E-003

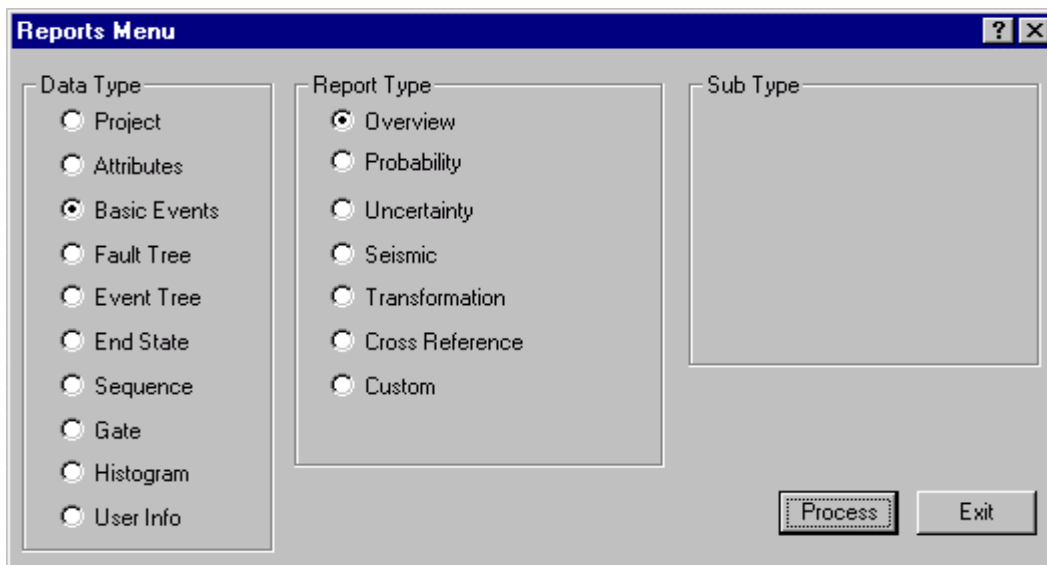
11. REPORTING BASIC EVENT INFORMATION

Section 11 describes how to **generate reports of basic event data** stored in SAPHIRE.

- ◆ Explain the various basic event information reports available in SAPHIRE.
- ◆ Display various basic event information reports.

11.1 Basic Event Report Information

□ To report basic event information, select **Report** from the menu bar.



□ Select **Basic Events** and then you can choose from several different report options.

Basic Events Overview Report

BASIC EVENTS OVERVIEW REPORT									
Family: DEMO									
Event Number	Primary Name Description	Secondary Name Init/ Process	Comp. ID	Hazard	Flag	Type	System	Location	Fail Mode
1	C-CV-A CCS Train A pump discharge check valve	C-CV-A	C-CV-A			CV	CCS	FZ1	A1

Basic Events Probability Report

BASIC EVENTS PROBABILITY REPORT					
Family: DEMO			Case: ALTERNATE		
Event Number	Primary Name	Calc Type	Mean Probability	Lamda	Tau
1	C-CV-A	1	1.000E-004	+0.000E+000	+0.000E+000

Basic Events Uncertainty Values Report

BASIC EVENTS UNCERTAINTY VALUES REPORT					
Family: DEMO			Case: ALTERNATE		
Event Number	Primary Name	Distrib. Type	Mean Probability	Uncertainty Value	Correlation Class
1	C-CV-A	L	1.000E-004	3.000E+000	1

Event Transformation Reference Report

EVENT TRANSFORMATION REFERENCE REPORT				
Family : DEMO				
Event Number	Event Name	Type	Level Susceptibilities	Referenced Events
1	C-CV-A	---	YNNNNNNNNNNNNNNNN	No References Located

Event X-Reference Report

Several Cross Reference reports are available. Choose from sequence, system, or end state cut set cross reference reports, or the **system logic** cross reference report.

Event X-Reference - (DEMO)

Case: ☒ Alternate ☐ Base

Analysis Type: RANDOM

Name	Description
<FALSE>	System Generated Success Event
<INIT>	System Generated Initiating Event
<PASS>	System Generated Ignore Event
<TRUE>	System Generated Failure Event
C-CV-A	CCS Train A pump discharge check valve
C-CV-B	CCS Train B pump discharge check valve
C-MOV-1	CCS suction isolation valve
C-MOV-A	CCS Train A pump discharge isolation valve
C-MOV-B	CCS Train B pump discharge isolation valve
C-PUMP-A	CCS Train A motor-driven pump
C-PUMP-B	CCS Train B motor-driven pump
CCS	CCS FAILS TO SPRAY WATER INTO THE CONTAINMENT

Cut Set:

Event-System Logic Reference Report

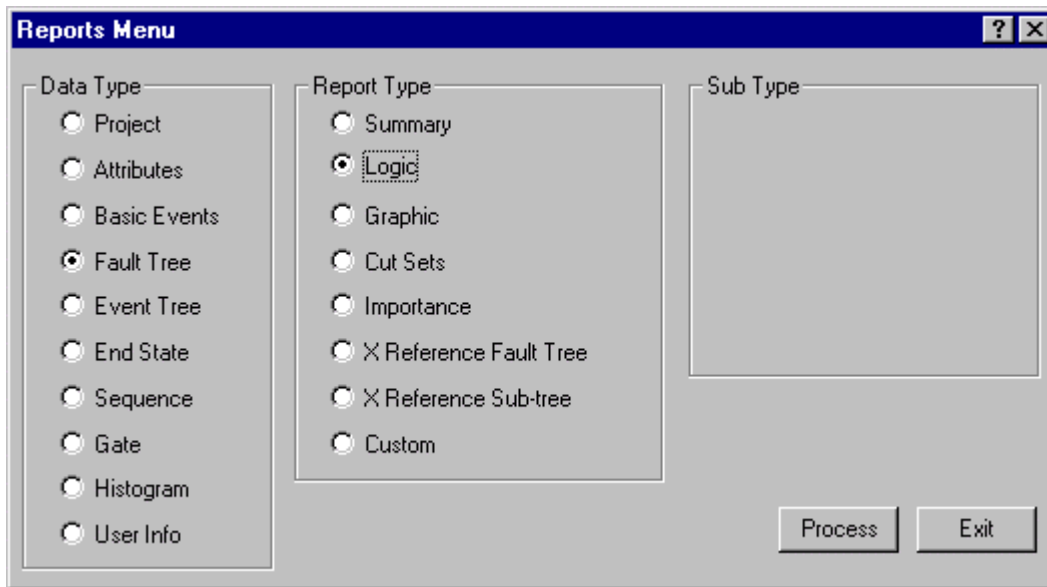
EVENT-SYSTEM LOGIC REFERENCE REPORT		
Family: DEMO		
Event Number	Event Name	System Names
1	C-CV-A	CCS

12. REPORTING SYSTEM RESULTS

Section 12 describes how to generate reports of fault tree (system) cut set results.

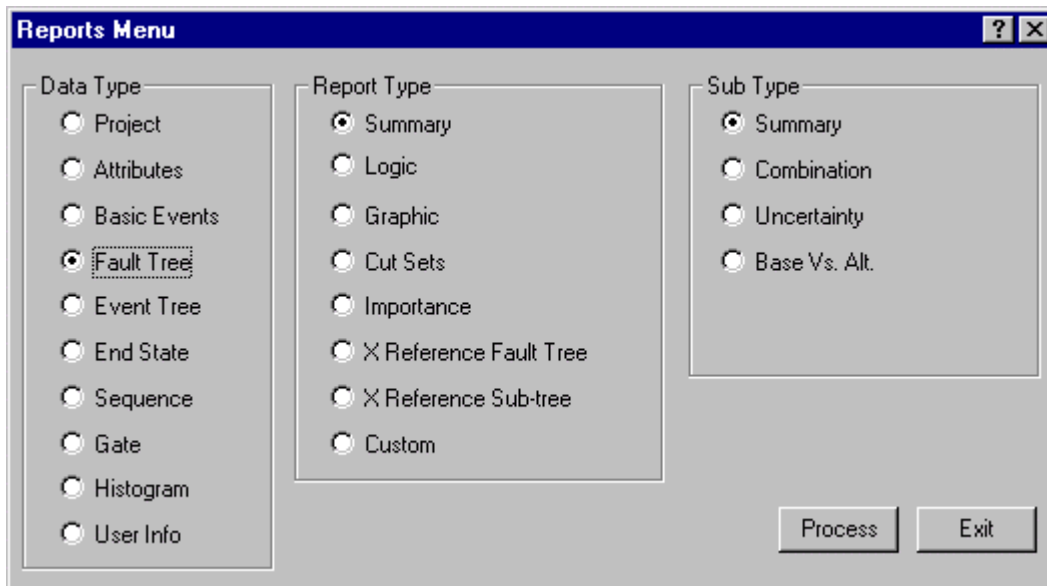
- ◆ Explain the various fault tree information reports available in SAPHIRE.
- ◆ Display various fault tree information reports.

12.1 System Report Menus and Examples



- To report fault tree information, select **REPORTS** from the main menu.
- Select **Fault Tree** and then you can choose from several different report options.

12.1.1 System Summary Reports



The 'Reports Menu' dialog box contains three sections of radio buttons. The 'Data Type' section has options: Project, Attributes, Basic Events, Fault Tree (selected), Event Tree, End State, Sequence, Gate, Histogram, and User Info. The 'Report Type' section has options: Summary (selected), Logic, Graphic, Cut Sets, Importance, X Reference Fault Tree, X Reference Sub-tree, and Custom. The 'Sub Type' section has options: Summary (selected), Combination, Uncertainty, and Base Vs. Alt. At the bottom right are 'Process' and 'Exit' buttons.

System Brief Summary Report

SYSTEM BRIEF SUMMARY REPORT		
Family: DEMO		Case: CURRENT
Analysis: RANDOM		
System Name	Description	MinCut Upper Bound
CCS	Containment Cooling System fault tree	2.120E-002

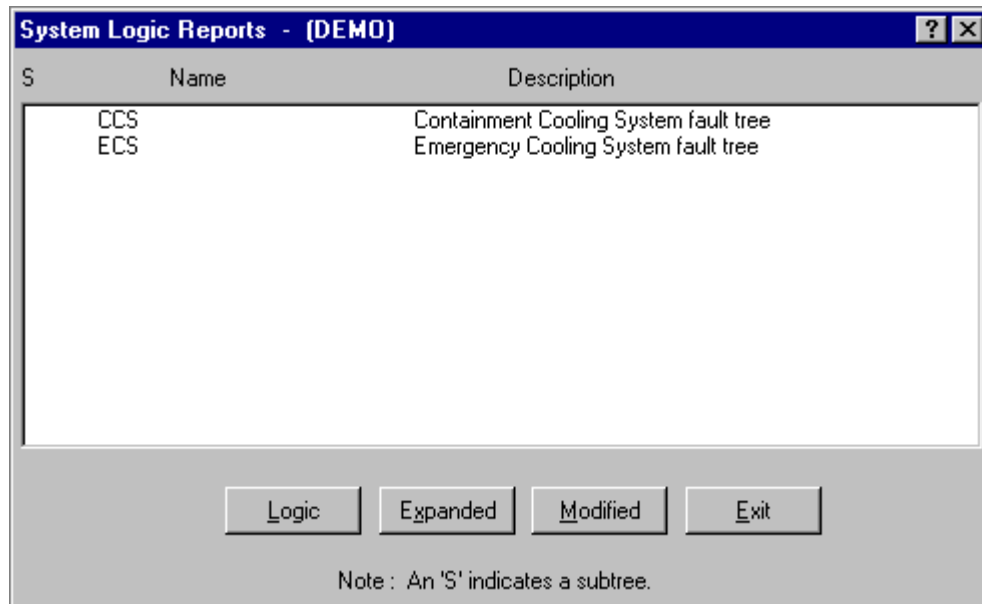
System Combination Report

SYSTEM COMBINATION REPORT				
Family: DEMO		Case: CURRENT		
Analysis: RANDOM				
No.	System Name	Mincut	Mean	No. of Cutsets
1	CCS	2.120E-002	2.259E-002	15

System Uncertainty Values Report

SYSTEM UNCERTAINTY VALUES REPORT						
Analysis: RANDOM			Family: DEMO		Case: CURRENT	
Number	System Name	Mean Median	MinCut Stand. Dev.	5th Perc. 95th Perc.	Minimum Maximum	Seed Size
1	CCS	2.259E-002 8.997E-003	2.120E-002 3.976E-002	1.544E-003 8.464E-002	5.481E-004 4.272E-001	46047 1000

12.1.2 System Logic Reports



Logic Report (transfers not expanded)

SYSTEM LOGIC REPORT		
Family: DEMO		System: CCS
Gate Name	Type	Inputs
CCS	OR	CCS-SUPPLY, CCS-TRAINS
CCS-SUPPLY	OR	C-MOV-1-FAILS, TANK
C-MOV-1-FAILS	OR	DG-B, C-MOV-1
CCS-TRAINS	AND	CCS-TRAIN-A, CCS-TRAIN-B
CCS-TRAIN-A	OR	C-CV-A, C-MOV-A, DG-A, C-PUMP-A
CCS-TRAIN-B	OR	C-CV-B, C-MOV-B, C-PUMP-B, DG-B

Expanded Logic Report (transfers expanded)

SYSTEM EXPANDED LOGIC REPORT		
Family: DEMO		System: CCS
Gate Name	Type	Inputs
CCS	OR	CCS-SUPPLY, CCS-TRAINS
CCS-SUPPLY	OR	C-MOV-1-FAILS, TANK
C-MOV-1-FAILS	OR	DG-B, C-MOV-1
CCS-TRAINS	AND	CCS-TRAIN-A, CCS-TRAIN-B
CCS-TRAIN-A	OR	C-CV-A, C-MOV-A, DG-A, C-PUMP-A
CCS-TRAIN-B	OR	C-CV-B, C-MOV-B, C-PUMP-B, DG-B

12.1.3 System Cut Set Reports

System Cut Sets - (DEMO)

Case: ☒ Alternate ☐ Base

Analysis Type: RANDOM

Name	Description
CCS	Containment Cooling System fault tree
ECS	Emergency Cooling System fault tree

Buttons: Cut Set, Quantified, Detailed, Exit

System Cut Set Report Example

SYSTEM CUT SETS REPORT		
Family : DEMO	Analysis : RANDOM	
System : CCS	Case : ALTERNATE	
Cut No.	Size	ALTERNATE CUT SETS
-----	-----	-----
1	1	C-MOV-1
2	1	DG-B
3	1	TANK
4	2	C-CV-A, C-CV-B
5	2	C-CV-A, C-MOV-B
6	2	C-CV-A, C-PUMP-B
7	2	C-CV-B, C-MOV-A
8	2	C-CV-B, C-PUMP-A
9	2	C-CV-B, DG-A
10	2	C-MOV-A, C-MOV-B
11	2	C-MOV-A, C-PUMP-B
12	2	C-MOV-B, C-PUMP-A
13	2	C-MOV-B, DG-A
14	2	C-PUMP-A, C-PUMP-B
15	2	C-PUMP-B, DG-A

System Quantified Cut Set Report

SYSTEM CUT SETS (QUANTIFICATION) REPORT				
Family : DEMO		Analysis : RANDOM		
System : CCS		Case : ALTERNATE		
Mincut Upper Bound : 2.120E-002				
Cut No.	% Total	% Cut Set	Prob/ Freq.	ALTERNATE CUT SETS
1	94.3	94.3	2.0E-002	DG-B
2	99.0	4.7	1.0E-003	C-MOV-1
3	99.5	0.4	1.0E-004	C-MOV-B, DG-A
4	99.8	0.2	6.0E-005	C-PUMP-B, DG-A
5	99.9	0.1	2.5E-005	C-MOV-A, C-MOV-B
6	100.0	0.0	1.5E-005	C-MOV-A, C-PUMP-B
7	100.0	0.0	1.5E-005	C-MOV-B, C-PUMP-A
8	100.0	0.0	9.0E-006	C-PUMP-A, C-PUMP-B
9	100.0	0.0	2.0E-006	C-CV-B, DG-A
10	100.0	0.0	5.0E-007	C-CV-A, C-MOV-B
11	100.0	0.0	5.0E-007	C-CV-B, C-MOV-A
12	100.0	0.0	3.0E-007	C-CV-A, C-PUMP-B
13	100.0	0.0	3.0E-007	C-CV-B, C-PUMP-A
14	100.0	0.0	1.0E-007	TANK
15	100.0	0.0	1.0E-008	C-CV-A, C-CV-B

12.1.4 System Importance Reports

System Importance - (DEMO)

Case: ☒ Alternate ☐ Base Analysis Type: RANDOM

Name	Description
CCS	Containment Cooling System fault tree
ECS	Emergency Cooling System fault tree

Importance Special Importance Sort Criteria Exit

System Importance Sort

Select the Sort Criteria

Sort Options

☐ Name

☐ Probability of Failure

☐ Occurrence Count

☒ F-V or Birnbaum

☐ Risk Reduction

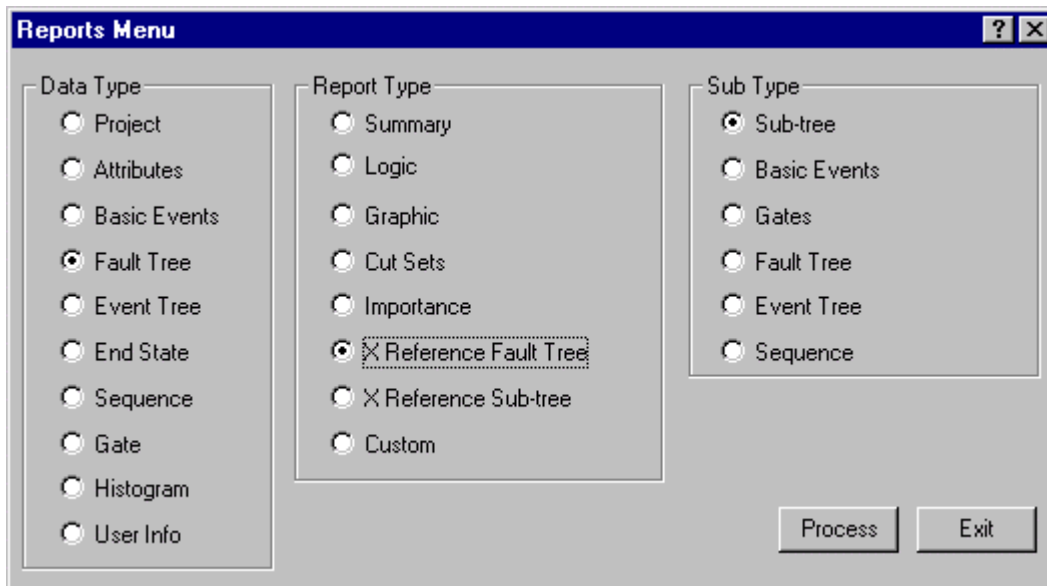
☐ Risk Increase

OK Cancel

System FV Importance Report

SYSTEM IMPORTANCE MEASURES REPORT					
Family : DEMO		Analysis : RANDOM			
System : CCS		Case : ALTERNATE			
(Sorted by Fussell-Vesely Importance)					
Event Name	Num. of Occ.	Probability of Failure	Fussell- Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio
DG-B	1	2.000E-002	9.421E-001	1.727E+001	4.716E+001
C-MOV-1	1	1.000E-003	4.621E-002	1.048E+000	4.716E+001
DG-A	3	2.000E-002	7.479E-003	1.007E+000	1.365E+000
C-MOV-B	4	5.000E-003	6.486E-003	1.006E+000	2.282E+000
C-PUMP-B	4	3.000E-003	3.891E-003	1.003E+000	2.285E+000
C-MOV-A	3	5.000E-003	1.869E-003	1.001E+000	1.371E+000
C-PUMP-A	3	3.000E-003	1.121E-003	1.001E+000	1.372E+000
C-CV-B	4	1.000E-004	1.297E-004	1.000E+000	2.288E+000
C-CV-A	3	1.000E-004	3.739E-005	1.000E+000	1.373E+000
TANK	1	1.000E-007	4.616E-006	1.000E+000	4.716E+001

12.1.5 System X-Reference Reports



The 'Reports Menu' dialog box is shown with three columns of radio button options. The 'Data Type' column includes Project, Attributes, Basic Events, Fault Tree (selected), Event Tree, End State, Sequence, Gate, Histogram, and User Info. The 'Report Type' column includes Summary, Logic, Graphic, Cut Sets, Importance, X Reference Fault Tree (selected and highlighted with a dashed border), X Reference Sub-tree, and Custom. The 'Sub Type' column includes Sub-tree (selected), Basic Events, Gates, Fault Tree, Event Tree, and Sequence. 'Process' and 'Exit' buttons are at the bottom right.

Data Type	Report Type	Sub Type
<input type="radio"/> Project	<input type="radio"/> Summary	<input checked="" type="radio"/> Sub-tree
<input type="radio"/> Attributes	<input type="radio"/> Logic	<input type="radio"/> Basic Events
<input type="radio"/> Basic Events	<input type="radio"/> Graphic	<input type="radio"/> Gates
<input checked="" type="radio"/> Fault Tree	<input type="radio"/> Cut Sets	<input type="radio"/> Fault Tree
<input type="radio"/> Event Tree	<input type="radio"/> Importance	<input type="radio"/> Event Tree
<input type="radio"/> End State	<input checked="" type="radio"/> X Reference Fault Tree	<input type="radio"/> Sequence
<input type="radio"/> Sequence	<input type="radio"/> X Reference Sub-tree	
<input type="radio"/> Gate	<input type="radio"/> Custom	
<input type="radio"/> Histogram		
<input type="radio"/> User Info		

Process Exit

System - Sequence X-Reference Report

SYSTEM / SEQUENCE REFERENCE REPORT	
Family: DEMO	
System Name	<Event Trees> and Sequences using this System
CCS	<LOSP>, 2, 3

13. SYSTEM SENSITIVITY ANALYSIS

Section 13 describes how to perform fault tree (system) sensitivity studies including basic event data modifications and fault tree logic changes. The use of Change Sets to make basic event data modifications is described.

- ◆ Discuss the steps involved in performing fault tree sensitivity analysis.
- ◆ List the various ways to modify fault tree logic.
- ◆ List the two ways data changes can be made to the database.
- ◆ Describe the two different types of change sets.
- ◆ Explain the three different system analysis options and when each option should be used.

13.1 Overview of Steps Involved in Performing a Fault Tree Sensitivity Analysis

- ① If fault tree logic changes are to be made (e.g., adding a basic event, removing a basic event, or changing an OR-gate to an AND-gate), make the changes using the graphical fault tree editor.
- ② If data changes are to be made, enter data modifications by either ☐
 - Changing the data "permanently" in the **Modify → Basic Events** option
 - Changing the data "temporarily" using Change Sets

Then, use the **Generate** option to "process" the basic event changes so that they will be used for subsequently performed SAPHIRE operations such as quantifying cut sets, displaying cut sets, and generating reports.

- ③ Update the fault tree cut sets in the **Fault Tree → Fault Trees List** dialog using the appropriate pop-up menu option ☐ **Solve**, **Cut Sets → Update**, or **Quantify**.

13.2 Modifying Fault Tree Logic

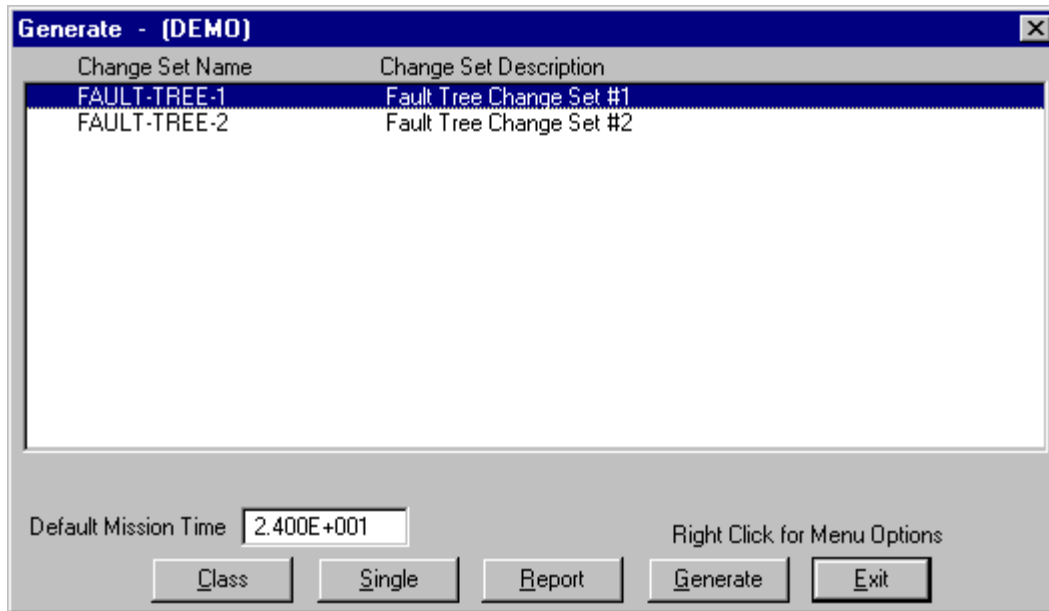
- ◆ The fault tree logic can be changed by using the graphical editor in the **Fault Tree → Edit Graphics**. See [Section 5](#) for detailed instructions.
- ◆ Alternate ways of modifying fault tree logic include:
 - ◇ Using the **Fault Tree → Edit Logic**
 - ◇ Replacing system logic with MAR-D .FTL files

13.3 Making a "Permanent" Data Change in MODIFY Data Base

- To enter basic event data, select **Modify** from the menu bar. Then select **Basic Events**.
 - To modify data for an existing event, highlight the event you want to edit, right-click to invoke the pop-up menu, and select the **Modify** option.
 - The **Generate** option from the main menu bar must be used before the data is available for SAPHIRE operations.

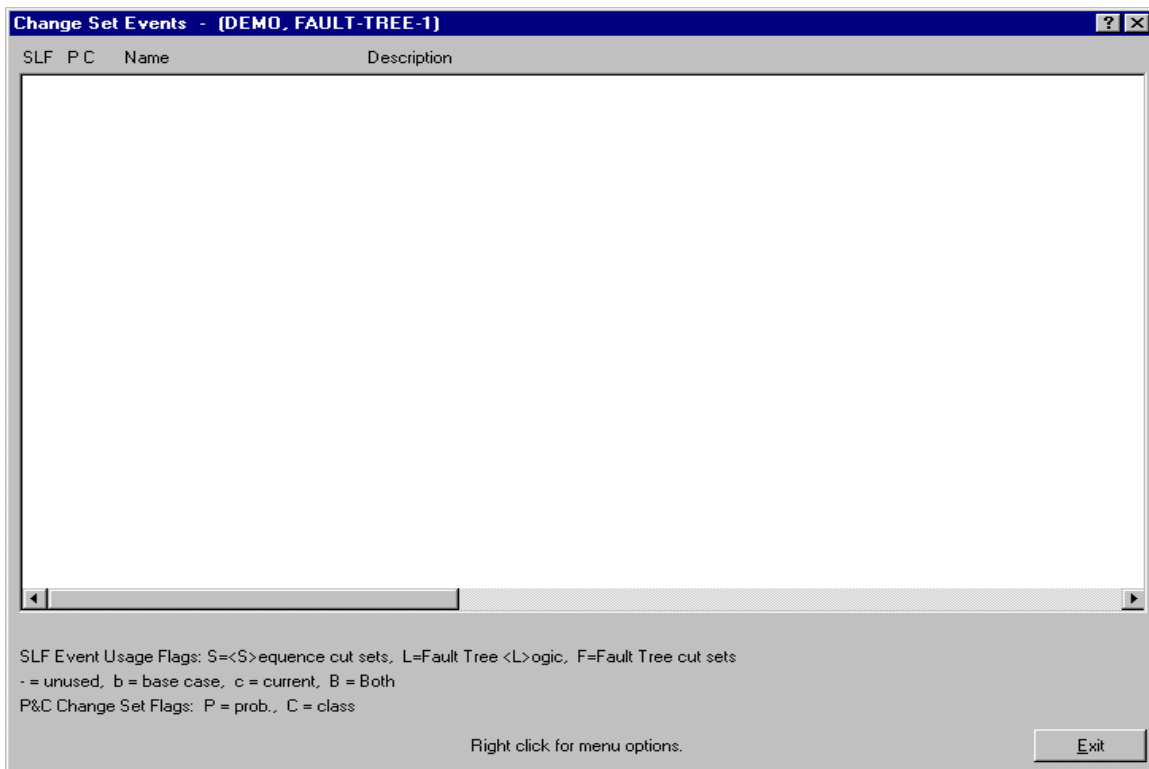
13.4 Making a "Temporary" Data Change by Using Change Sets

- Select **Generate** from the menu bar.
- To create a Change Set, right-click to invoke the pop-up menu, select **Add**, and enter the Change Set name and description.
- As shown in the figure, two Change Sets (named FAULT-TREE-1 and FAULT-TREE-2) were created in this example.



- To make a data change in the Change Set named FAULT-TREE-1, highlight the Change Set, choose the **Single** button.
- To create a Class Change for the FAULT-TREE-2 Change Set, highlight the Change Set, choose the **Class** button.

The Change Set Select Event Dialog



- Right-click to invoke the pop-up menu and select the **Add** option. Double-click on the event to be modified. In this example, event **C-CV-A** was edited.

The Change Set Data Entry Dialog

Event Probability Changes

Names	Attributes			Susceptibilities															
	Comp Id	F/Mode	Location	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<P>C-CV-A	C-CV-A	A1	FZ1	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<A>C-CV-A																			
<T>	Type	System	Train																
Category:	CV	CCS																	

Base		Random Failure Data		Current	
1		Calculation Type	- <BLANK> No Change		
1.000E-004		Mean Failure Probability	1.000E-003		
+0.000E+000		Lambda	-----E----		
+0.000E+000		Tau	-----E----		
+0.000E+000		Mission Time	-----E----		

L		Uncertainty Data		Current	
Log Normal		Distribution Type	- <BLANK> No Change		
3.000E+000		Name	[empty]		
-----E----			-----E----		
1		Correlation Class	[empty]		

Process Flag	
<input type="checkbox"/>	[dropdown arrow]

Leave Current Values blank if no changes are desired.

Ok **Cancel**

- The Event Probability Changes dialog allows you to enter changes on the right side of the dialog.
- In this example, the probability field was changed from 1.0E-4 to 1.0E-3.

The Class Change Dialog

Edit Event Class - (DEMO, FAULT-TREE-2) [?] [X]

Note: Leave values blank if no changes are desired.

Event Attributes Mask

Names					Susceptibilities									
Primary	<input type="text"/>	Comp Id	<input type="text"/>	System	<input type="text"/>	Train	<input type="text"/>	1	2	3	4	5	6	7
								<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Uncert. Corr. Class	<input type="text"/>	Category	<input type="text"/>	Location	<input type="text"/>	F/Mode	<input type="text"/>	Type	<input type="text"/>	9	10	11	12	13
								CV		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Failure/Seismic Data

Calculation Type: **1 - Probability**

Prob/Freq/Median Fail Accel:

Lamda/Screening G-Level:

Tau:

Mission Time:

Uncertainty Data

Distribution Type: **- <BLANK> No Char**

Name:

Value 1:

Value 2:

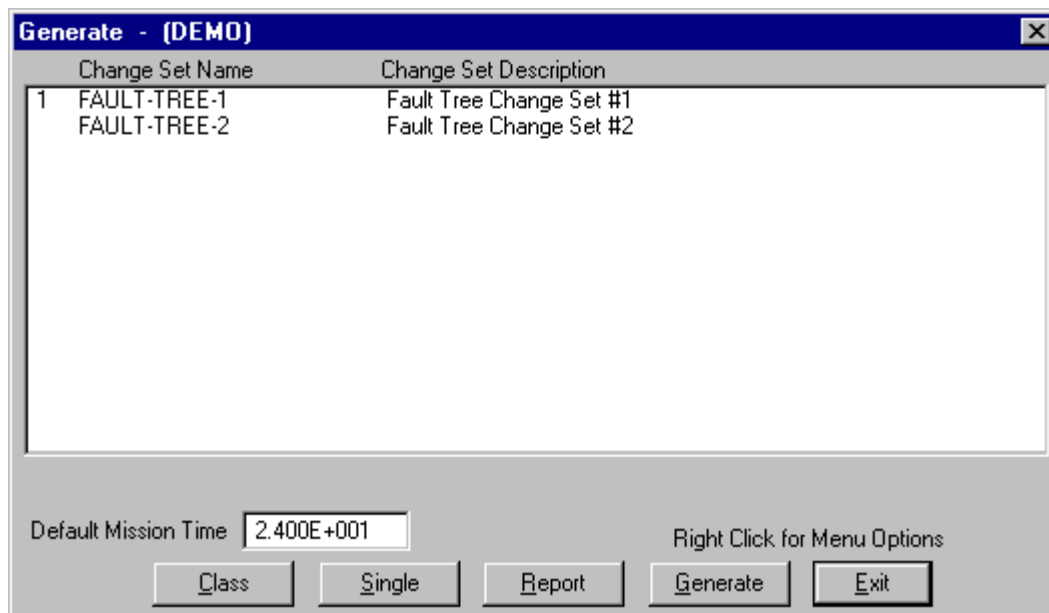
Correlation Class:

Process Flag: ☐

[Ok] [Clear] [Cancel]

- Enter the attributes that define the events to be changed. In this example, Type was specified as CV.
- Enter the new data. In this example, the probability was changed to 2.0E-4.
- One class change is allowed for each Change Set.

Generating Changes for One Change Set

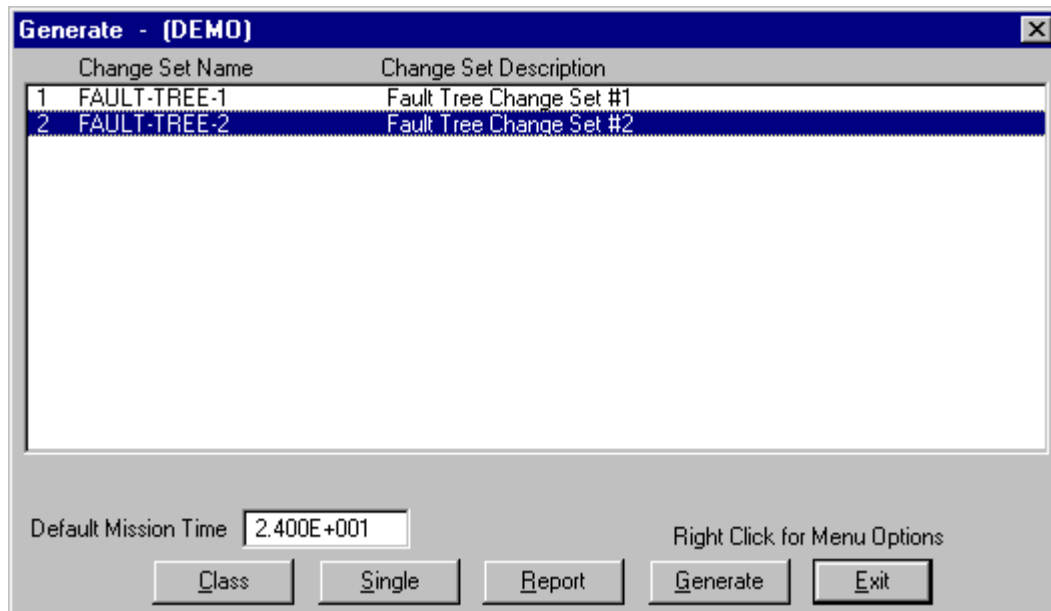


- To invoke only the FAULT-TREE-1 Change Set, double-click on the Change Set.
- The number 1 will appear in the # column.
- Choose the **Generate** button and proceed as directed.
- To report the changes, choose the **Report** button, then select the Affected Events radio button.

Report Changes

Events Affected By Change Sets					
Family : DEMO					
Event Name	Calc Type	Lambda Mission	Tau Curr Prob	Change Set	Cng Type
C-CV-A	1	0.000E+00	0.000E+00	FAULT-TREE-1	P
		0.000E+00	1.000E-03		

Generating Changes for Two Change Sets



- When invoking more than one Change Set, the order that they are selected dictates which changes have precedence.
- In this example, the FAULT-TREE-1 Change Set was marked, and then the FAULT-TREE-2 Change Set was marked.
- Note the numbering in the # column. This will cause the FAULT-TREE-2 changes to override the FAULT-TREE-1 changes where the same basic event is affected by both Change Sets.
- Choose the **Generate** button and continue as directed.
- To report the changes, choose the **Report** button, then select the Affected Events radio button.

Generating Changes - Compare Reports

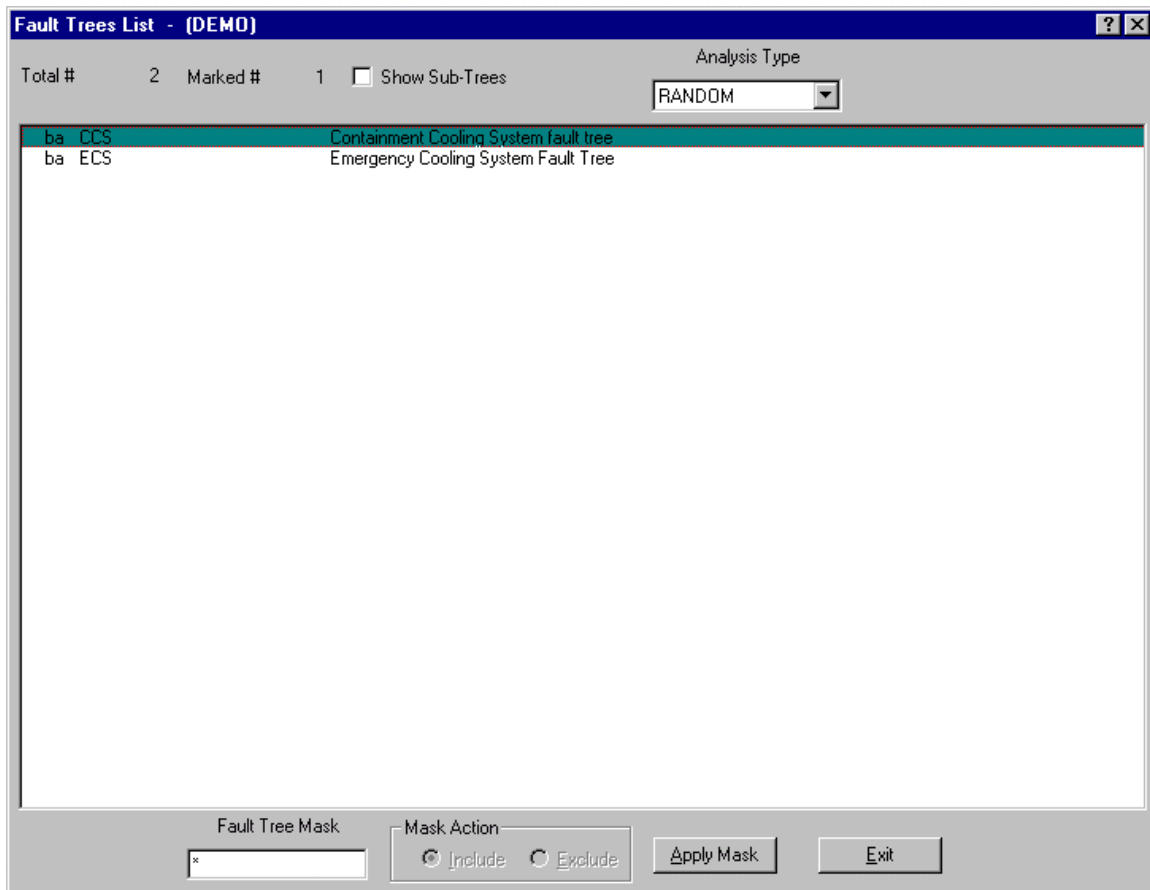
Events Affected By Change Sets					
Family : DEMO					
Event Name	Calc Type	Lambda Mission	Tau Curr Prob	Change Set	Cng Type
C-CV-A	1	0.000E+00	0.000E+00	PROPAGATE	C
		0.000E+00	2.000E-04		
C-CV-B	1	0.000E+00	0.000E+00	PROPAGATE	C
		0.000E+00	2.000E-04		
E-CV-A	1	0.000E+00	0.000E+00	FAULT-TREE-2	C
		0.000E+00	2.000E-04		
E-CV-B	1	0.000E+00	0.000E+00	FAULT-TREE-2	C
		0.000E+00	2.000E-04		

In the example above, the FAULT-TREE-1 had been selected first, and then FAULT-TREE-2.

Events Affected By Change Sets					
Family : DEMO					
Event Name	Calc Type	Lambda Mission	Tau Curr Prob	Change Set	Cng Type
C-CV-A	1	0.000E+00	0.000E+00	MODIFYDB	P
		0.000E+00	1.000E-03		
C-CV-B	1	0.000E+00	0.000E+00	MODIFYDB	C
		0.000E+00	2.000E-04		
E-CV-A	1	0.000E+00	0.000E+00	FAULT-TREE-2	C
		0.000E+00	2.000E-04		
E-CV-B	1	0.000E+00	0.000E+00	FAULT-TREE-2	C
		0.000E+00	2.000E-04		

If the FAULT-TREE-2 had been selected first, and then FAULT-TREE-1, the resulting affected basic events would be as shown above.

13.5 Analyzing System Cut Sets



- Select **Fault Tree** from the menu bar.
- Mark the fault trees using the mask function, or individually using the mouse.
- Right-click to invoke the pop-up menu.
- Select the appropriate option from the pop-up menu.

Analysis Options

Type of Model or Data Modification	Analysis Option		
	Generate Cut Sets	Cut Set Update	Quantification
Fault tree/event tree logic changes	✓		
Data changes - all probabilities decreased	⌚✓	✓	
Data changes - any probabilities increased	✓		
Data changes involve house event settings	✓		
Cut set truncation limit increased (i.e., from 1.0E-8 to 1.0E-7)	⌚✓	✓	
Cut set truncation limit decreased (i.e., from 1.0E-8 to 1.0E-10)	✓		
Following use of the cut set editor (e.g., to add recovery events)		✓	
No fault tree/sequence logic in model (in cases where cut sets were loaded via Mar-D, without fault tree/event tree sequence logic)		✓ (house event changes or cut sets edited)	✓ (probability changes)

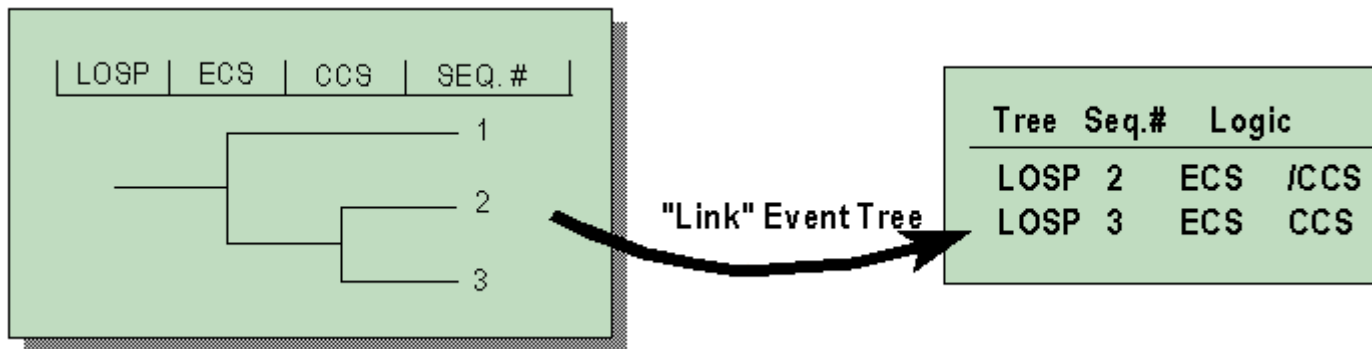
14. LINKING EVENT TREE SEQUENCES

Section 14 describes SAPHIRE **event tree linking** and **process** required to link event tree sequences.

- ◆ Define “linking” event trees.
- ◆ Explain the link event tree process available in SAPHIRE.
- ◆ Perform the link event tree process.
- ◆ Provide a description for each of the sequence generation headers.
- ◆ Display the logic for an event tree.

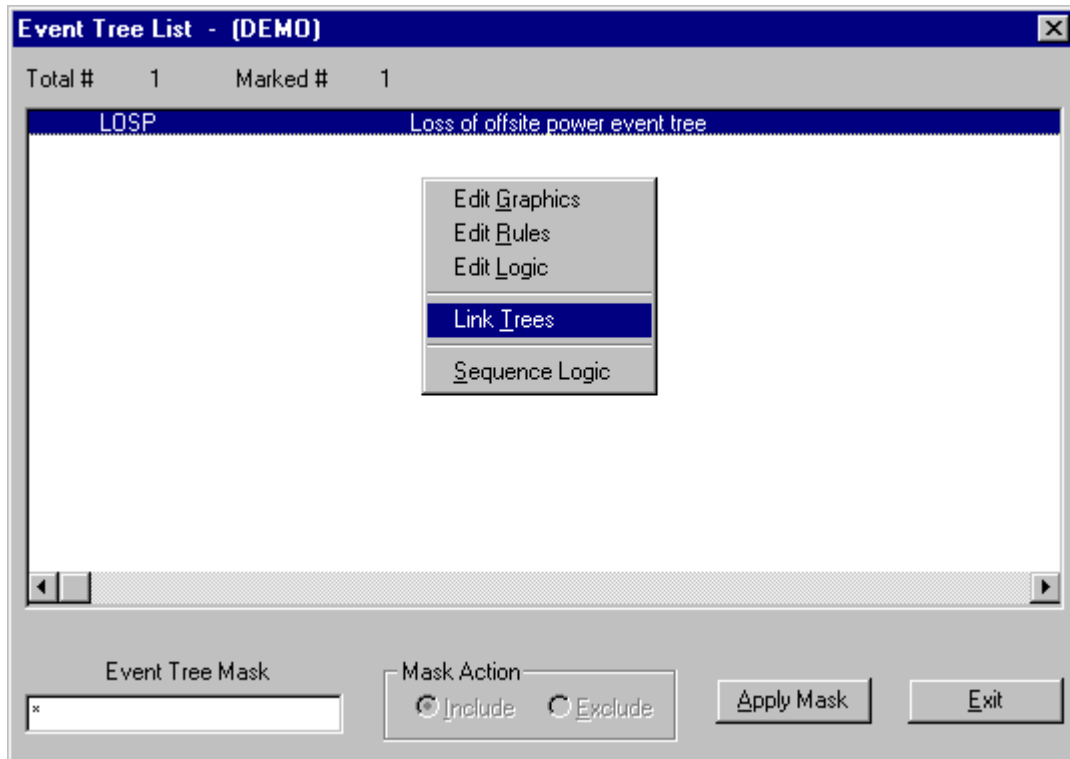
14.1 Linking Event Trees

“Linking” event trees is the process of generating of sequence logic using the event tree graphical files.



14.2 Menus and Options for Linking Event Tree Sequences

- Select **Event Tree** from the menu bar.

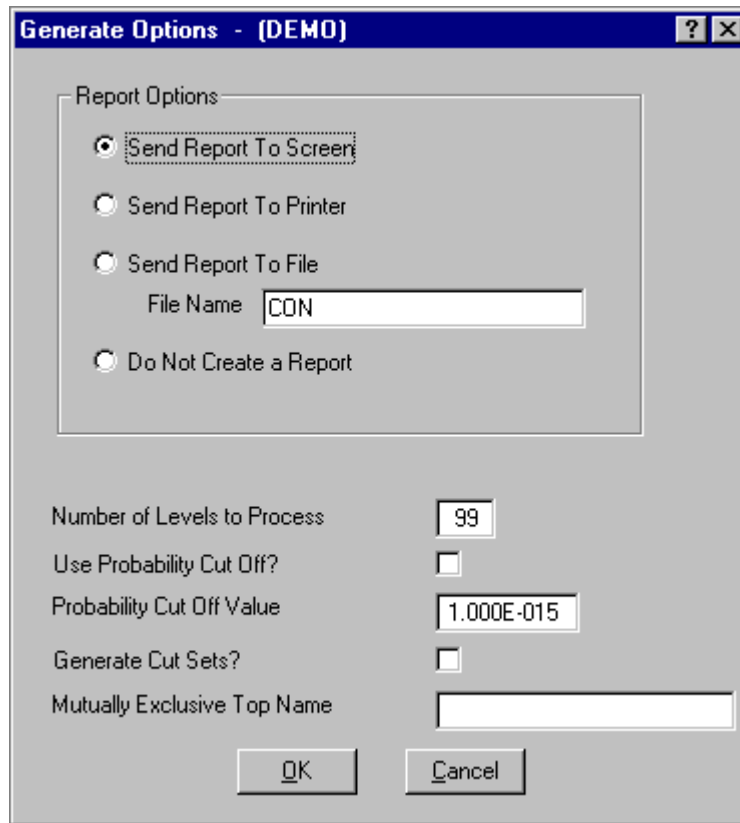


- The event trees are now displayed.
- Mark the event trees using the mask feature, or individually, using the mouse.
- Right-click to invoke the pop-up menu and select the **Link Trees** option.

14.3 Reporting Event Tree Sequence Logic

- ◆ You can view the event tree sequence logic in several ways:
 - ◇ By selecting one of the Report Options radio buttons on the **Generate Options** dialog, you can send the logic to the screen or printer, or you can exit SAPHIRE and use a text editor to view the file (e.g., LOSP.TXT).
 - ◇ Select **Report** from the menu bar, then select the **Sequence → Logic** radio buttons to preview, print or create a file containing a report of the sequence logic.
- ◆ The automatic sequence naming will add a "-" to the sequence identifier each time an event tree transfer is encountered.

Sequence Generation Information



The image shows a Windows-style dialog box titled "Generate Options - (DEMO)". It contains several controls for configuring report generation. At the top, under the "Report Options" section, there are four radio buttons: "Send Report To Screen" (which is selected), "Send Report To Printer", "Send Report To File", and "Do Not Create a Report". Below the "Send Report To File" option is a text field labeled "File Name" containing the text "CON". Further down, there are five more controls: a text field for "Number of Levels to Process" with the value "99", a checkbox for "Use Probability Cut Off?" which is unchecked, a text field for "Probability Cut Off Value" with the value "1.000E-015", a checkbox for "Generate Cut Sets?" which is unchecked, and a text field for "Mutually Exclusive Top Name" which is empty. At the bottom of the dialog are "OK" and "Cancel" buttons.

- Enter the desired parameters on the dialog and choose the **OK** button to link event tree sequences.

Send Report to File

This radio button is selected by default. A default report name is provided that will be created in the family subdirectory. Optionally, a different filename may be input.

Send Report to Screen

By selecting this radio button, "CON" is automatically placed in the File Name field and the report is displayed in the Report Viewer.

Send Report to Printer

By selecting this radio button, "PRN" is automatically placed in the File Name field and the report is printed on your Windows default printer.

Do Not Create a Report

By selecting this radio button, the File Name field is blank and a report is not generated.

Number of Levels to Process

A level is a transfer to another event tree (subtree). The default (99) will generate sequences for all subtrees. If the level is specified as less than 99, only that number of subtrees will be processed.

The next three options are used for the large event tree methodology.

Use Probability Cut Off

By default the box is unchecked. **If the tops are independent and are treated as probability values (i.e., not fault tree logic)**, then the event tree sequence logic can be truncated on probability. Each top is treated as a basic event with its probability assumed to be the value of its split fraction.

Probability Cutoff Value

Enter the truncation value if you checked the **Use Probability Cutoff** check box.

Generate Cut Sets

If you check the box, a sequence "cut set" will be generated when the sequence logic is generated. Each top, whether failed or successful, is treated as a basic event and placed in the cut set for the generated sequence. Consequently, each sequence will end up with a single "cut set" representing the probability for each top event.

Mutually Exclusive Top Name

May be left blank. This allows you to specify a top event (associated with a fault tree) that will be added to each sequence as a success event. The top will appear in the logic as a complemented system and will be treated accordingly when the sequence is solved. The purpose is to provide a method of removing illegal combinations of events.

15. GENERATING EVENT TREE CUT SETS

Section 15 describes how to generate event tree cut sets. **Model preparation** prior to generating cut sets is discussed, and the various **analysis and truncation options** are described. Cut set **display features** are also presented.

- ◆ Indicate several prerequisites for generating event tree cut sets.
- ◆ Generate event tree cut sets.
- ◆ View generated event tree cut set results.

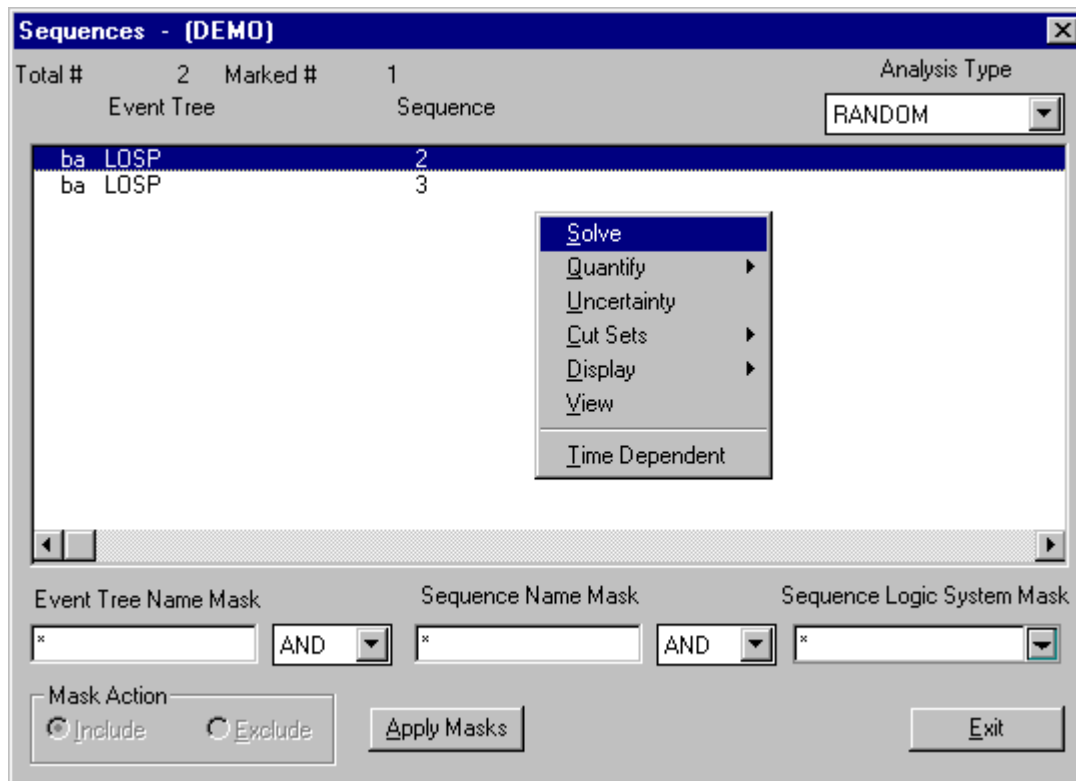
15.1 Prerequisites for Generating Event Tree Cut Sets

- ① Event tree logic was created by using the event tree graphical editor.
- ② Event tree logic was "linked" using **Event Tree → Link Trees**.
- ③ Basic event data was added through the **Modify → Basic Events** option.
- ④ Basic event data was prepared for model processing by using the **Generate** option.

Note: System cut sets do not need to be generated prior to generating sequence cut sets.

15.2 Menus and Options for Event Tree Cut Set Generation

- Select **Sequence** from the menu bar.



- Mark the sequences using the mask feature, or mark sequences individually using the mouse.
- Right-click to invoke the pop-up menu and select the **Solve** option.

b - flags sequences with existing base case cut sets

a - flags sequences with existing current case cut sets

Analysis Type

Select the RANDOM analysis type for material covered in this class. The other analysis types are provided for performing fire, flood, seismic, and other hazard analyses.

Solve

This option uses the event tree logic and fault trees associated with event tree top events. The sequence frequency is quantified using the minimal cut set upper bound approximation.

Cut Set Generation Cutoff Values

Cut Set Generation Cutoff Values

☒ Cutoff Cut Set Probability < Cutoff Value 1.000E-008

☐ Cutoff by Event Probability Min < Cutoff Value 1.000E-003

Cutoff by ☐ Size ☐ Zone ☒ None > Cutoff Value 6

☐ Solve Sequence W/Fault Trees Flag Set Name [Dropdown]

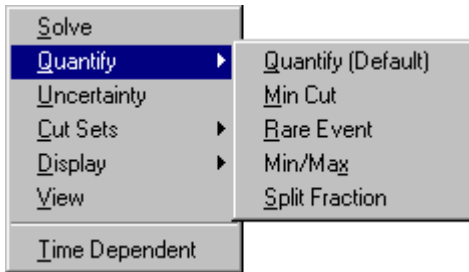
☐ Auto Apply Recovery Rules

NOTE: To perform Event Probability truncation you must also specify Cut Set Probability truncation and the associated cutoff value.

OK Cancel

- Enter the desired truncation parameters on the dialog, and choose the **OK** button to begin generating cut sets.
- ▶ **Cutoff by Cut Set Probability** – If you check this box, then those cut sets below the value in the **< Cutoff Value** field will not be retained.
- ▶ **Cutoff by Event Probability** – If you if you check this box, then you must also check the **Cutoff by Cut Set Probability** box. This option will retain cut sets comprised of basic events that are above the **Min < Cutoff Value** even if the cut set is below the **Cut Set Probability Cutoff Value**.
- ▶ **Cut Set Size Truncation** – If you check this box, then cut sets having more events than specified in the **> Cutoff Value** field will not be retained. If you check the **Zone** box, then cut sets having more *Zone Flagged Events* than specified in the **> Cutoff Value** field will not be retained. If you leave both boxes unchecked, then the number of events in a cut set will be not affect whether the cut set is retained or discarded.
- ▶ **Solve Sequence with Fault Trees** –If you check this box, then fault tree logic will be used. If the box is unchecked, previously generated fault tree cut sets will be used.
- ▶ **Flag Set Name** – A Flag Set containing House event settings may be specified in this field. If blank, the Flag Set specified in **Modify → Event Trees → Sequences → Flags Name** will be used if a Flag Set was specified.
- ▶ **Auto Apply Recovery Rules** – If you check box, any recovery rules associated with the sequence(s) marked will automatically be applied after the sequence(s) cut sets have been generated.

Quantify



This sub-menu provides options for requantifying the sequence frequencies for existing current case cut sets. These options are designed to quickly requantify the cut sets when data changes have been made. (Note: if data changes increase the failure probability of an event, the Solve option should be used instead.)

Split Fraction

Provides a minimal cut set upper bound estimation using the previously calculated system results for the failed or successful systems in the sequence. This option does not generate cut sets, and is only appropriate for event trees with independent top events where the top events are treated as probabilities, not fault trees.

Min Max Quantification

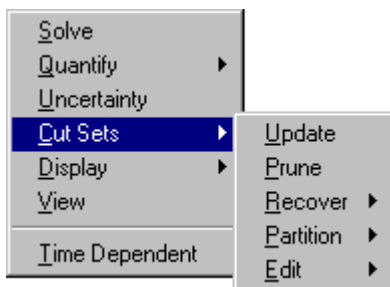
The Min-Max quantification option quantifies the current case cut sets using the exact probability quantification algorithm.

see Section 8, System Cut Set Generation

Uncertainty

Performs Monte Carlo or Latin Hypercube uncertainty analysis for the selected sequence individually or combined. Sequence uncertainty analysis is discussed further in Section 16.

Cut Sets



This sub-menu provides options for cut set manipulation.

Cut Set Update

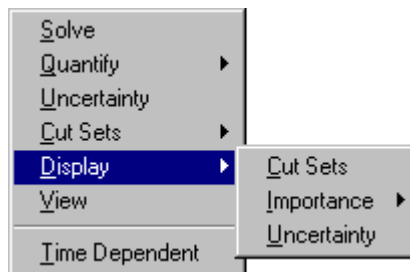
This option uses the existing current case cut sets (unless the user specifies that base case cut sets are to be used instead). Non-minimal cut sets are eliminated and the sequence frequency is quantified using the minimal cut set upper bound approximation.

Prune Cut Sets

This is one of the options that allows you to eliminate cut sets from a selected sequence that contains events which conflict in some way with one another. This option has been superseded by the "Cut Set, Recover" option.

Displaying Event Tree Cut Set Results

- To display sequence cut sets, select **Sequence** from the menu bar.
- Highlight the sequence that you want to view.



- Right-click to invoke the pop-up menu and select the **Display → Cut Sets** option.

Viewing Sequence Cut Sets

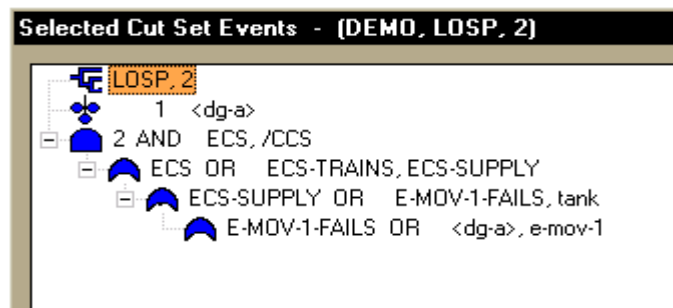
- The sequence cut sets and minimal cut set upper bound approximation of the sequence frequency are now displayed.

Selected Cut Sets - (DEMO, LOSP, 2)

Cut Set No.	Frequency	% Total	Events
1	4.600E-002	95.04	DG-A
2	2.300E-003	4.75	E-MOV-1
3	5.750E-005	0.12	E-MOV-A, E-MOV-B
4	3.450E-005	0.07	E-MOV-A, E-PUMP-B
5	3.450E-005	0.07	E-MOV-B, E-PUMP-A
6	2.070E-005	0.04	E-PUMP-A, E-PUMP-B
7	1.150E-006	0.00	E-CV-A, E-MOV-B
8	1.150E-006	0.00	E-CV-B, E-MOV-A
9	6.900E-007	0.00	E-CV-A, E-PUMP-B
10	6.900E-007	0.00	E-CV-B, E-PUMP-A
11	2.300E-008	0.00	E-CV-A, E-CV-B

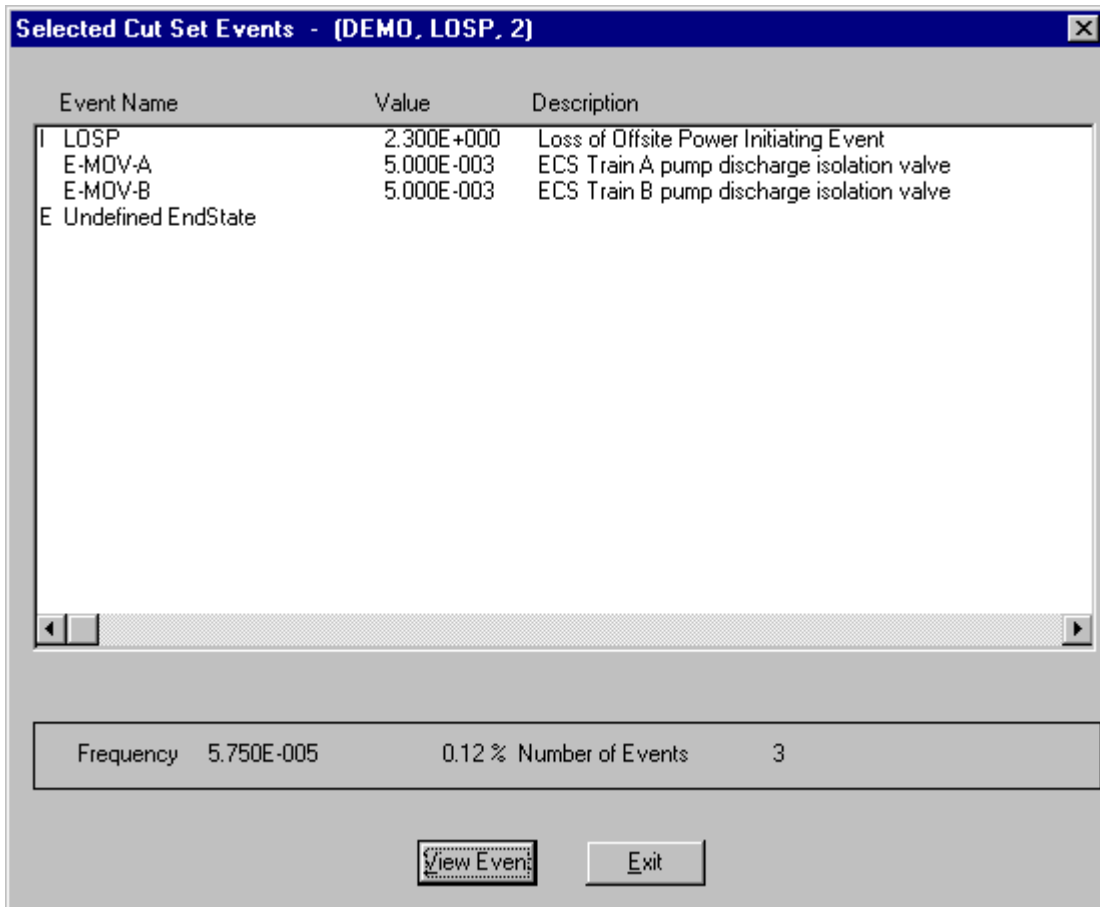
Min Cut 4.840E-002 Num 11 This List==> 4.840E-002 100.00 % Num 11

- To view the events in a cut set, highlight the cut set, choose the **View Cut Set** button.
- To find out where the events in the cut set came from, *right-click* on a cut set and select the **Path Search** option.



Viewing Basic Event Information for an Individual Cut Set

- The basic events, their failure probabilities and descriptions are now displayed.



The screenshot shows a window titled "Selected Cut Set Events - [DEMO, LOSP, 2]". It contains a table with three columns: "Event Name", "Value", and "Description". The table lists four events: "LOSP", "E-MOV-A", "E-MOV-B", and "E Undefined EndState". Below the table, there is a summary bar showing "Frequency: 5.750E-005", "0.12 %", "Number of Events: 3". At the bottom, there are two buttons: "View Event" and "Exit".

Event Name	Value	Description
I LOSP	2.300E+000	Loss of Offsite Power Initiating Event
E-MOV-A	5.000E-003	ECS Train A pump discharge isolation valve
E-MOV-B	5.000E-003	ECS Train B pump discharge isolation valve
E Undefined EndState		

Frequency: 5.750E-005 0.12 % Number of Events: 3

View Event Exit

- To view individual basic event information, highlight the event and choose the **View Event** button.
- To return to the list of cut sets, choose the **Exit** button.

15.3 Advanced Features

In complex PRA models, it may be necessary to use special features prior to cut set generation and/or after cut set generation.

Prior to event tree sequence cut set generation:

- ◇ **Flag Sets** may be used to set House events or Process Flags on a sequence-by-sequence basis.

After event tree sequence cut set generation:

- ◇ **Recover Cut Sets** can be used as a rule-based automated way to add "recovery events" to the cut sets.

16. SEQUENCE UNCERTAINTY ANALYSIS

Section 16 describes **uncertainty analysis** for event tree sequences. The concept of **performing uncertainty analysis** via Monte Carlo or Latin Hypercube sampling is discussed.

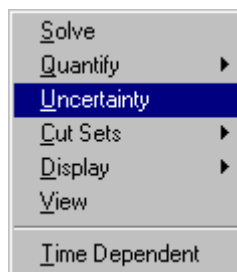
- ◆ Explain the two types of uncertainty analysis techniques available in SAPHIRE.
- ◆ List the different uncertainty distributions supported by SAPHIRE.
- ◆ Perform sequence uncertainty analysis.
- ◆ Display sequence uncertainty analysis results.

16.1 Sequence Uncertainty Analysis

- ◆ Uncertainty analysis calculates the variability of the sequence frequency resulting from uncertainties in the basic event probabilities and the initiating event frequency.
- ◆ SAPHIRE provides two uncertainty analysis techniques:
 - ◇ **Simple Monte Carlo sampling**
 - ◇ **Latin Hypercube sampling**

16.2 Menus and Options for Performing Sequence Uncertainty Analysis

- Select **Sequence** from the menu bar.



- Mark the sequence(s), right-click to invoke the pop-up menu.
- Select the **Uncertainty** option. The sequence uncertainty may be calculated for each sequence individually or as a group.

Uncertainty Calculation Values

- Enter the uncertainty calculation values on the dialog:

Uncertainty Calculation Values

Number of samples to use in simulation: 1000

Seed for random number generator: 0

Uncertainty type: ☒ Single, ☐ Group, ☐ Family

Uncertainty method: ☐ Latin Hypercube, ☒ Monte Carlo

Ground Accel. Level: [Dropdown]

Intermediate Values:

Output Values: ☐

File Name: [Text Box]

Ok Cancel

- Uncertainty results will be **displayed** briefly on the dialog following the uncertainty calculation.

Uncertainty Type

Specify whether the marked sequences are to be calculated individually, as a group, or for the family (if all sequences are marked).

Uncertainty Method

Specify **Monte Carlo** or **Latin Hypercube**.

Number of Samples

Input the number of samples. (A larger number of samples will provide more accurate results but will require more time.)

Random Number Seed

Enter a value for the random number generator seed or accept the default. Enter zero to obtain a random seed from the system clock.

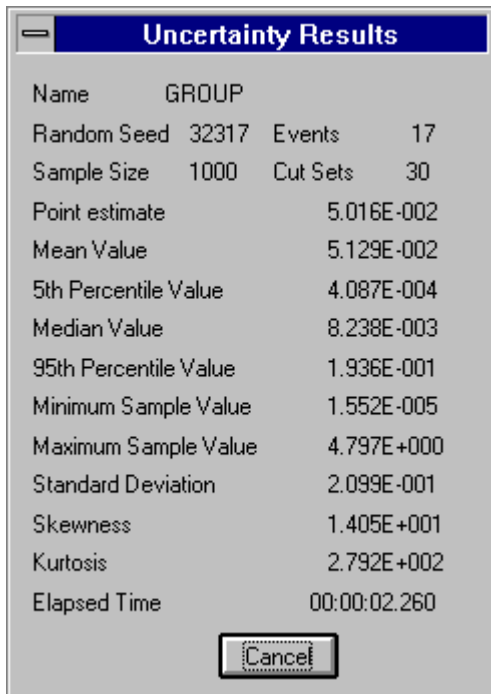
Ground Acceleration Level

Enter a Ground Acceleration Level if seismic uncertainty is selected.

Output Intermediate Values

OPTIONAL: To save intermediate sample results to a disk file for review, select the Output Values check box and provide the Output file name.

Uncertainty Results



Name	GROUP
Random Seed	32317
Events	17
Sample Size	1000
Cut Sets	30
Point estimate	5.016E-002
Mean Value	5.129E-002
5th Percentile Value	4.087E-004
Median Value	8.238E-003
95th Percentile Value	1.936E-001
Minimum Sample Value	1.552E-005
Maximum Sample Value	4.797E+000
Standard Deviation	2.099E-001
Skewness	1.405E+001
Kurtosis	2.792E+002
Elapsed Time	00:00:02.260

□ Uncertainty results will be displayed briefly on the screen following the uncertainty calculation.

□ Uncertainty results for each sequence *when calculated individually* can be displayed:

- ▶ Select **Sequence** from menu bar, and highlight the individual sequence
- ▶ Right-click to invoke the pop-up menu and select the **Display → Uncertainty** option.

□ Uncertainty results for the *project* can be displayed:

- ▶ Select **Sequence** from the menu bar, mark all the sequences in the family
- ▶ Right-click to invoke the pop-up menu and select the **Display → Uncertainty** option.

□ Note: GROUP uncertainty results are displayed *only* on the screen immediately after the analysis. These results are not available from the **Display** option.

17. SEQUENCE IMPORTANCE ANALYSIS

Section 17 describes the various **sequence importance measures** available in SAPHIRE. Also shown is **how to calculate** the importance measures using SAPHIRE.

- ◆ Explain the use and meaning of importance measures.
- ◆ Define the importance measures that are available in SAPHIRE for sequences.
- ◆ Discuss the steps used to calculate sequence importance measures.
- ◆ View ratio importance measure results.
- ◆ View difference importance measure results.

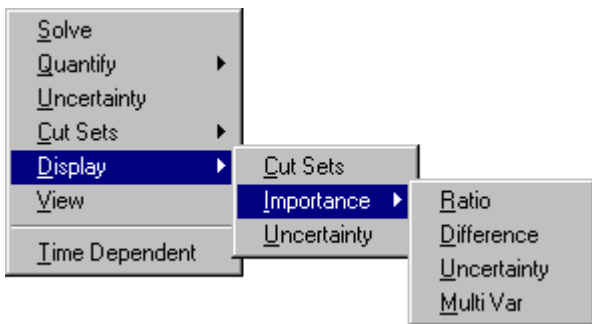
17.1 Sequence Importance Measures

- ◆ Importance measures provide “reliability-worth” information about basic events appearing in the cut sets of an event tree sequence.
- ◆ Components showing high relative importance may be candidates for either (1) close monitoring to ensure that the component does not degrade over time or (2) design changes to increase the component reliability.
- ◆ *Ratio* or *Difference* or *Uncertainty* importances can be selected.
 - ◇ When you select *Ratio Importances* “**Fussell-Vesely Importance**, **Risk Reduction Ratio**, and **Risk Increase Ratio** will be calculated, displayed, and reported.
 - ◇ When you select *Interval Importances* “**Birnbaum Importance**, **Risk Reduction Interval**, **Risk Increase Interval** will be calculated, displayed, and reported.

17.2 Menus and Options for Calculating Sequence Importance Measures

- Select the **Sequence** from the menu bar.

- Highlight an individual sequence, right-click to invoke the pop-up menu.



- Select **Importance**, then one of the sub-menu options. **Ratio** was selected in this example.

- To analyze the importance of a group of sequences, highlight the desired sequences, then select **Importance**.

View Sequence Importances

- The Ratio importances are now displayed.

Importance Measures - (DEMO, 2)

Sort: F-V

Event Name	# of Occur	Probability	F-V	Risk Reduc. Ratio	Risk Incr. Ratio
LOSP	11	2.300E+000	1.000E+000	-----	4.348E-001
DG-A	1	2.000E-002	9.494E-001	1.975E+001	4.752E+001
E-MOV-1	1	1.000E-003	4.657E-002	1.049E+000	4.752E+001
E-MOV-A	3	5.000E-003	1.884E-003	1.002E+000	1.374E+000
E-MOV-B	3	5.000E-003	1.884E-003	1.002E+000	1.374E+000
E-PUMP-B	3	3.000E-003	1.130E-003	1.001E+000	1.375E+000
E-PUMP-A	3	3.000E-003	1.130E-003	1.001E+000	1.375E+000
E-CV-B	3	1.000E-004	3.768E-005	1.000E+000	1.376E+000
E-CV-A	3	1.000E-004	3.768E-005	1.000E+000	1.376E+000

Buttons: Description, Partition, Report, Exit

- Use the Report button on this dialog to write the importance measure to a file or printer. (Note that *Ratio* importances are displayed.)

- Alternately, the **Report → Sequence → Importance** option can be used to report sequence importances.

18. REPORTING SEQUENCE RESULTS

Section 18 describes how to **generate reports** of sequence cut set results.

- ◆ Explain the various sequence information reports available in SAPHIRE.
- ◆ Display various sequence information reports.

18.1 Sequence Report Menus and Examples

- To report sequence information, select **Report** from the menu bar.
- Select the **Sequence** radio button and then you can choose from several different report options.

18.1.1 Sequence Summary Reports

The screenshot shows the 'Reports Menu' dialog box with three columns of radio button options. The 'Data Type' column has 'Sequence' selected. The 'Report Type' column has 'Summary' selected. The 'Sub Type' column has 'Brief' selected. At the bottom right are 'Process' and 'Exit' buttons.

Data Type	Report Type	Sub Type
<input type="radio"/> Project	<input checked="" type="radio"/> Summary	<input checked="" type="radio"/> Brief
<input type="radio"/> Attributes	<input type="radio"/> Logic	<input type="radio"/> Summary
<input type="radio"/> Basic Events	<input type="radio"/> Cut Sets	<input type="radio"/> Combination
<input type="radio"/> Fault Tree	<input type="radio"/> Importance	<input type="radio"/> Uncertainty
<input type="radio"/> Event Tree	<input type="radio"/> Custom	
<input type="radio"/> End State		
<input checked="" type="radio"/> Sequence		
<input type="radio"/> Gate		
<input type="radio"/> Histogram		
<input type="radio"/> User Info		

Process Exit

Sequence Brief Summary Report

SEQUENCE BRIEF SUMMARY REPORT			
Family: DEMO		Case: CURRENT	
Analysis: RANDOM			
Event Tree Name	Sequence Name	Endstate Name	MinCut Upper Bound
LOSP	2	SMALL-RELEASE	4.840E-002
LOSP	3	LARGE-RELEASE	1.759E-003
TOTAL			5.015E-002

Sequence Combination Report

SEQUENCE COMBINATION REPORT					
		Family: DEMO			
Analysis: RANDOM				Case: CURRENT	
Seq. Number	Event Tree Name	Sequence Name	Mincut	Mean	Number Cutsets
1	LOSP	2	4.840E-002	4.784E-002	11
2	LOSP	3	1.759E-003	9.699E-003	19
TOTAL			5.015E-002	+0.000E+000	30

Sequence Uncertainty Values Report

SEQUENCE UNCERTAINTY VALUES REPORT						
Family: DEMO			Case: CURRENT			
Analysis: RANDOM						
Seq No	Event Tree Name	Sequence Name				
		Mean	MinCut	5th Perc.	Minimum	Seed
		Median	Stand. Dev.	95th Perc.	Maximum	Size
-----	-----	-----	-----	-----	-----	-----
1	LOSP	2				
		4.784E-002	4.840E-002	4.833E-004	3.020E-005	15817
		7.594E-003	1.646E-001	1.918E-001	2.183E+000	1000
2	LOSP	3				
		9.699E-003	1.759E-003	4.114E-006	5.675E-008	9697
		1.740E-004	1.416E-001	1.394E-002	3.934E+000	1000

18.1.2 Sequence Logic Reports

Sequence Logic - (DEMO)		
Event Tree	Name	Description
	LOSP	2
	LOSP	3

Continue

Exit

Sequence Logic Report

Sequence Logic Report			
Family : DEMO			
Seq. Number	Event Tree Name Initiating Event	Sequence Name Flag Set Name	

1	LOSP	2	
	LOSP		
	ECS	/CCS	
2	LOSP	3	
	LOSP		
	ECS	CCS	

18.1.3 Sequence Cut Set Reports

Sequence Cutsets - (DEMO) [?] [X]

Case: ☒ Alternate ☐ Base Analysis Type: RANDOM

Event Tree	Name	Description
LOSP	2	
LOSP	3	

[Cut Set] [Quantified] [Detailed] [Exit]

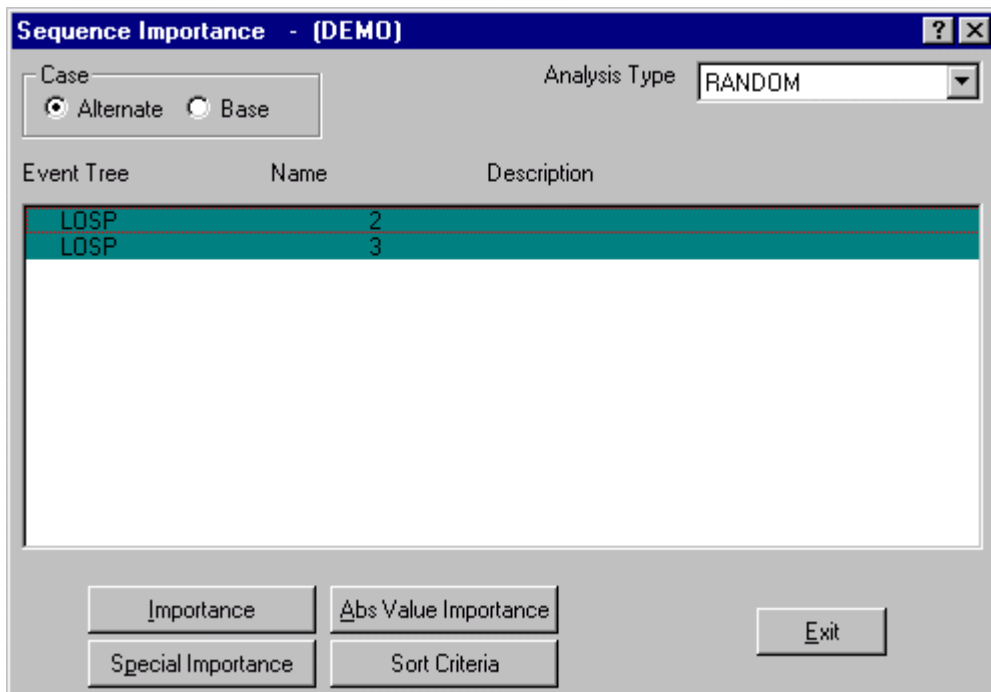
Sequence Cut Set Report

SEQUENCE CUT SETS REPORT			
Family	: DEMO	Sequence	: 2
Analysis	: RANDOM	Event Tree	: LO SP
Case	: ALTERNATE	Init. Event	: LO SP
Cut			
No.	Size	ALTERNATE CUT SETS	
1	1	DG-A	
2	1	E-MOV-1	
3	2	E-CV-A, E-CV-B	
4	2	E-CV-A, E-MOV-B	
5	2	E-CV-A, E-PUMP-B	
6	2	E-CV-B, E-MOV-A	
7	2	E-CV-B, E-PUMP-A	
8	2	E-MOV-A, E-MOV-B	
9	2	E-MOV-A, E-PUMP-B	
10	2	E-MOV-B, E-PUMP-A	
11	2	E-PUMP-A, E-PUMP-B	

Sequence Quantified Cut Set Report

SEQUENCE CUT SETS (QUANTIFICATION) REPORT				
Family	: DEMO	Sequence	: 2	
Analysis	: RANDOM	Event Tree	: LO SP	
Case	: ALTERNATE	Init. Event	: LO SP	
		Mincut Upper Bound	: 4.840E-002	
Cut	%	% Cut	Prob/	ALTERNATE CUT SETS
No.	Total	Set	Freq.	
1	95.0	95.0	4.6E-002	DG-A
2	99.7	4.7	2.3E-003	E-MOV-1
3	99.9	0.1	5.7E-005	E-MOV-A, E-MOV-B
4	99.9	0.0	3.4E-005	E-MOV-A, E-PUMP-B
5	100.0	0.0	3.4E-005	E-MOV-B, E-PUMP-A
6	100.0	0.0	2.0E-005	E-PUMP-A, E-PUMP-B
7	100.0	0.0	1.1E-006	E-CV-A, E-MOV-B
8	100.0	0.0	1.1E-006	E-CV-B, E-MOV-A
9	100.0	0.0	6.9E-007	E-CV-A, E-PUMP-B
10	100.0	0.0	6.9E-007	E-CV-B, E-PUMP-A
11	100.0	0.0	2.3E-008	E-CV-A, E-CV-B

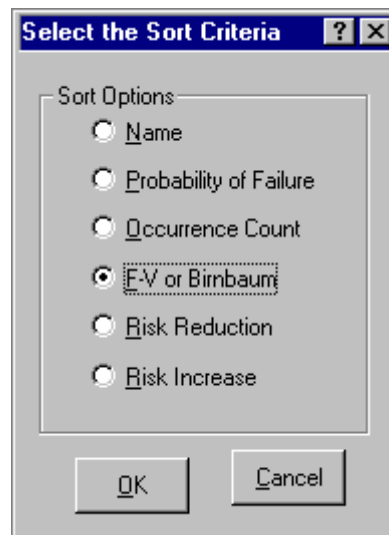
18.1.4 Sequence Importance Reports



The dialog box titled "Sequence Importance - (DEMO)" features a "Case" section with radio buttons for "Alternate" (selected) and "Base". To the right, the "Analysis Type" is set to "RANDOM" in a dropdown menu. Below this is a table with three columns: "Event Tree", "Name", and "Description". The table contains two rows: "LOSP" with "2" and "LOSP" with "3". At the bottom, there are five buttons: "Importance", "Abs Value Importance", "Special Importance", "Sort Criteria", and "Exit".

Event Tree	Name	Description
LOSP	2	
LOSP	3	

Sequence Importance Sort Options



The "Select the Sort Criteria" dialog box displays a "Sort Options" section with seven radio buttons. The "FV or Birnbaum" option is selected and highlighted with a dashed border. The other options are "Name", "Probability of Failure", "Occurrence Count", "Risk Reduction", and "Risk Increase". At the bottom are "OK" and "Cancel" buttons.

- ☐ Name
- ☐ Probability of Failure
- ☐ Occurrence Count
- ☒ FV or Birnbaum
- ☐ Risk Reduction
- ☐ Risk Increase

In this example the "FV or Birnbaum" sort option is selected.

Sequence Importance Measures Report

SEQUENCE IMPORTANCE MEASURES REPORT					
Family	: DEMO	Sequence : 2			
Analysis	: RANDOM	Event Tree : LOSP			
Case	: ALTERNATE	Init. Event : LOSP			
(Sorted by Fussell-Vesely Importance)					
Event Name	Num. of Occ.	Probability of Failure	Fussell- Vesely Importance	Risk Reduction Ratio	Risk Increase Ratio
-----	-----	-----	-----	-----	-----
LOSP	11	2.300E+000	1.000E+000	1.900E+038	4.347E-001
DG-A	1	2.000E-002	9.493E-001	1.975E+001	4.751E+001
E-MOV-1	1	1.000E-003	4.656E-002	1.048E+000	4.751E+001
E-MOV-B	3	5.000E-003	1.884E-003	1.001E+000	1.374E+000
E-MOV-A	3	5.000E-003	1.884E-003	1.001E+000	1.374E+000
E-PUMP-B	3	3.000E-003	1.130E-003	1.001E+000	1.374E+000
E-PUMP-A	3	3.000E-003	1.130E-003	1.001E+000	1.374E+000
E-CV-A	3	1.000E-004	3.768E-005	1.000E+000	1.376E+000
E-CV-B	3	1.000E-004	3.768E-005	1.000E+000	1.376E+000

19. EVENT TREE SENSITIVITY ANALYSIS

Section 19 describes **how to** perform event tree sensitivity studies including basic event data modifications and event tree **logic changes**. The use of Change Sets to make basic event data modifications is described.

- ◆ Discuss the steps involved in performing event tree sensitivity analysis.
- ◆ List the various ways to modify event tree logic.
- ◆ List the two ways data changes can be made to the database.
- ◆ Describe the two different types of change sets.
- ◆ Explain the three different sequence analysis options and when each option should be used.

19.1 Overview of Steps Involved in Performing an Event Tree Sensitivity Analysis

- ① If event tree logic changes are to be made, make changes to the event tree logic (e.g., add or delete a top event, or modify the event tree branches), and then use **Event Tree** → **Link Trees** to link the new event tree logic.
- ② If fault tree logic changes are to be made, make changes to the fault tree logic using the graphical fault tree or logic editor.
- ③ If data changes are to be made, enter data modifications by either ☐
 - changing the data "**permanently**" in the **Modify** → **Basic Events** menu,
 - changing the data "**temporarily**" using Change Sets.

Then, use the **Generate** option from the menu bar to "process" the basic event changes so that they will be used for subsequently performed SAPHIRE operations such as quantifying and displaying cut sets and generating reports.

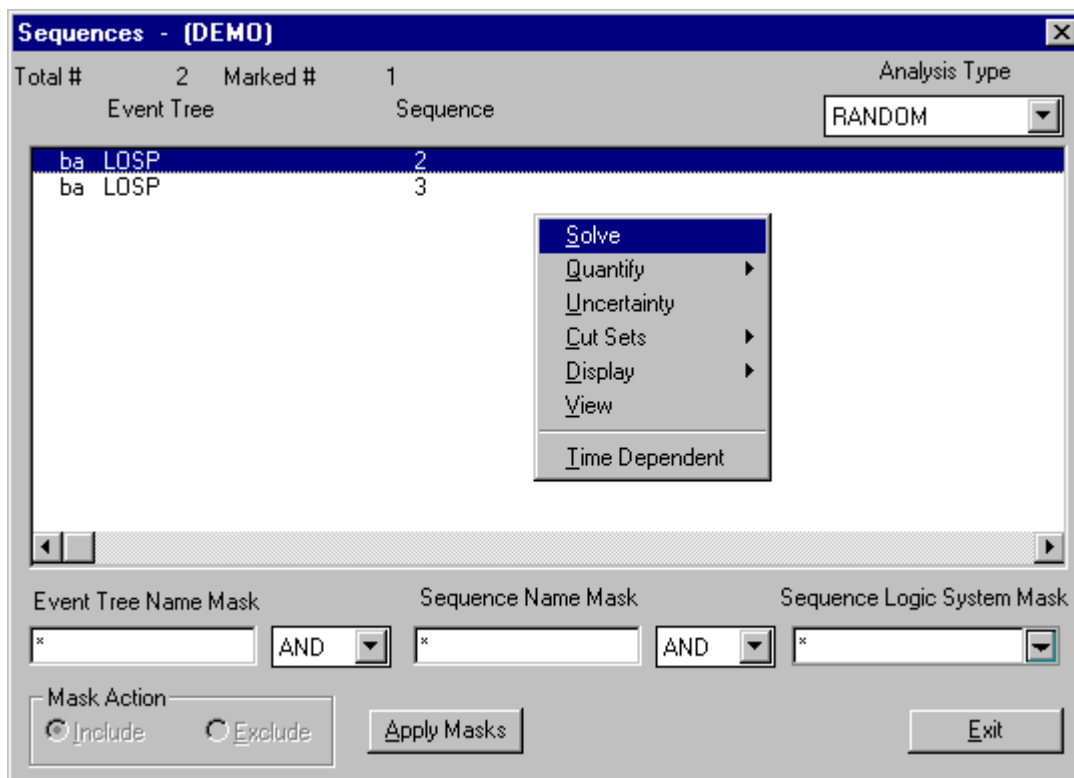
- ④ To update the event tree sequence cut sets select **Sequence** from the menu bar. Then right-click to invoke the pop-up menu and select the appropriate option ☐ **Solve, Cut Sets** → **Update**, or **Quantify**.

19.2 Modifying Event Tree Logic (or Fault Tree Logic Affecting the Event Tree)

- ◆ Event tree logic can be changed by using the graphical editor in the **Event Tree → Edit Graphics** menu.
- ◆ Fault tree logic can be changed by using the graphical editor in the **Fault Tree → Edit Graphics**.
- ◆ Alternate ways of modifying event tree logic include:
 - ◇ using the **Event Tree → Edit Logic**
 - ◇ replacing sequence logic with MAR-D .SQL files

19.3 Analyzing Event Tree Sequence Cut Sets

- Select **Sequence** from the menu bar.



- Mark the sequences using the mask features, or individually using the mouse.

- Right-click to invoke the pop-up menu and select the appropriate option □ **Solve**, **Cut Sets** → **Update**, or **Quantify**.

Solve

This option uses the event tree logic and fault trees associated with event tree top events. The sequence frequency is quantified using the minimal cut set upper bound approximation. This option is appropriate for all sensitivity studies where event tree logic is available; however, it will take longer than the **Cut Sets** → **Update** or **Quantify** options.

Quantify

This option uses the existing current case cut sets and requantifies the system probabilities. This option is designed to quickly requantify the cut sets when data changes have been made. (Note: if data changes *increase* the failure probability of an event, the **Solve** option should be used instead.) This option must be used if the event tree sequence has cut sets, but does not have sequence logic.

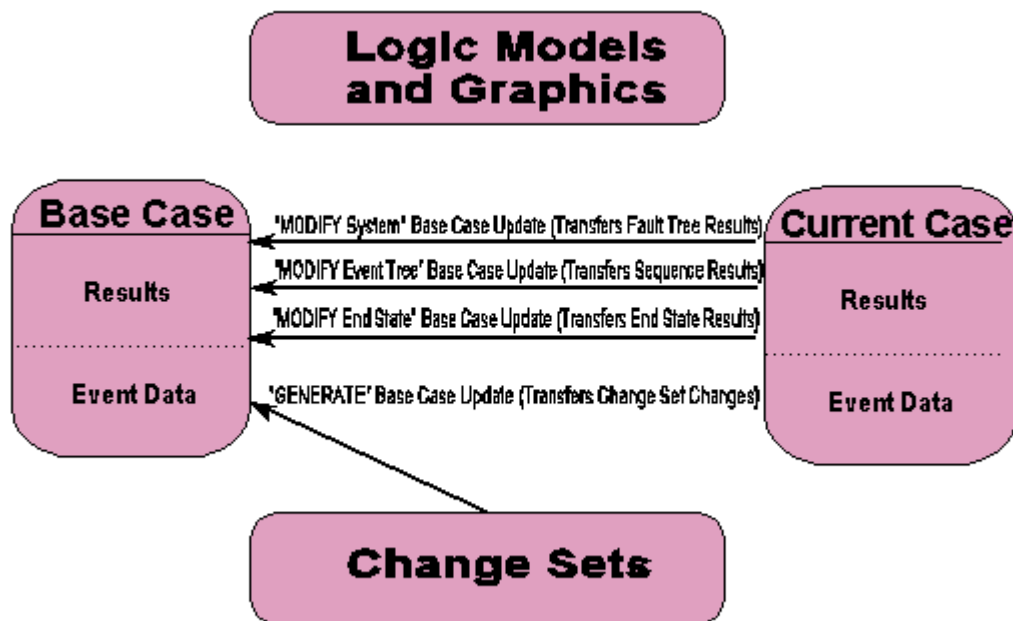
Cut Set Update

This option uses the existing current case cut sets (unless the user specifies that base case cut sets are to be used instead). Non-minimal cut sets are eliminated and the system probability is quantified using the minimal cut set upper bound approximation. This option may not be appropriate for the model or data changes performed (the user must decide when it is appropriate to use this option).

20. BASE CASE UPDATE

Section 20 describes how to perform a base case update on **event tree accident sequence** results and **system** results.

- ◆ Describe the difference between base case and current case.
- ◆ State the prerequisites before performing a base case update on both event tree accident sequences and system results.
- ◆ Perform a base case update on event tree accident sequence and system results.
- ◆ All results generated by SAPHIRE are stored in the current (alternate) case. These results change each time a new analysis is performed. To save the results that were just generated permanently, a base case update needs to be performed.
- ◆ Base case update is a means to store data and results in the family files as a **“permanent”** record.
- ◆ Base case data and results are changed by transferring the current case to the base case. Transferring the current case data and results into the base case gives a **“permanent”** record that can not be removed until another base case update is performed.
- ◆ By performing a base case update, these base case results can be readily compared to results from other sensitivity analyses.
- ◆ The various base case updates are shown graphically below.



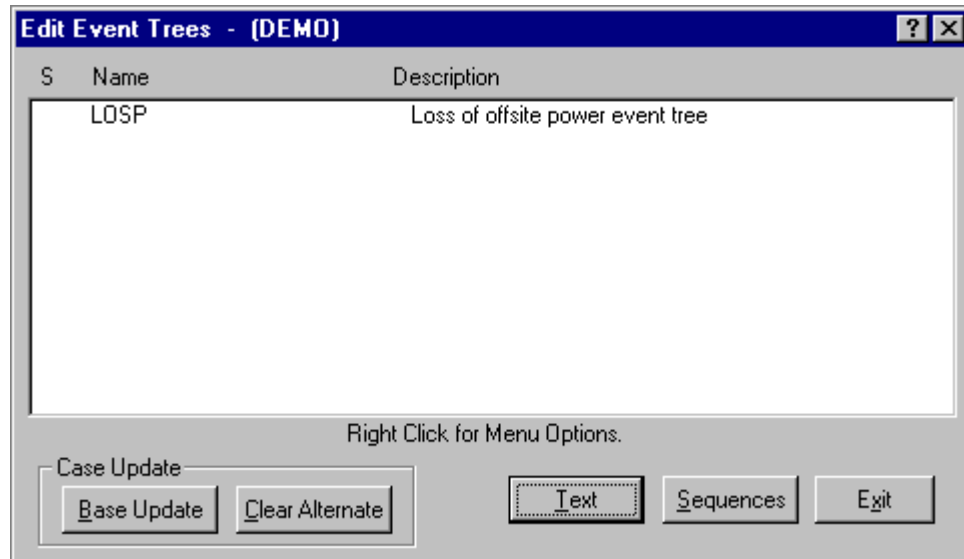
20.1 Event tree accident sequence results

- ◆ Prerequisites for sequence results base case update
 - ◇ Generate appropriate data changes for the analysis.
 - ◇ Analyze (i.e., generate cut sets) the accident sequences at a specified truncation level.
 - ◇ Review resulting cut sets for correctness.
 - ◇ Apply recovery rules to the accident sequence cut sets if required.
 - ◇ Perform uncertainty analysis if needed.

We are now ready to perform a base case update.

20.2 Menus and options for accident sequence base case update

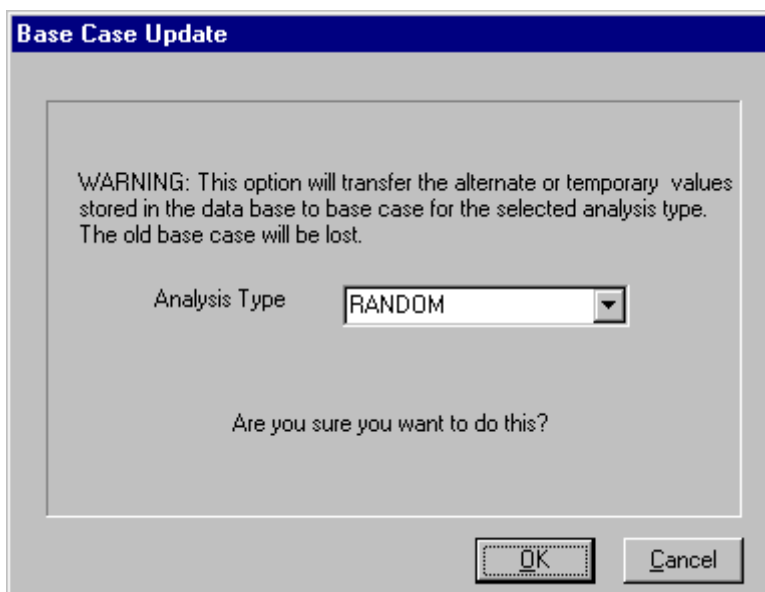
- Select the **Modify Event Trees** menu.



- Mark the event trees.
- Choose the **Base Update** button.

(The **Clear Alternate** button removes the results stored in the current (alternate) case.)

Base Case Update Dialog



- Choose the **OK** button to perform the base case update.
- The Analysis Type drop-down list gives you the opportunity to do a base case update on any one of the sixteen different analysis types listed.

Note: The default analysis type as shown in the [Define Constants] will be the default selection for the base case updated.

- To perform a base case update on any of the other analysis types, you must select the analysis type prior to choosing the **OK** button.

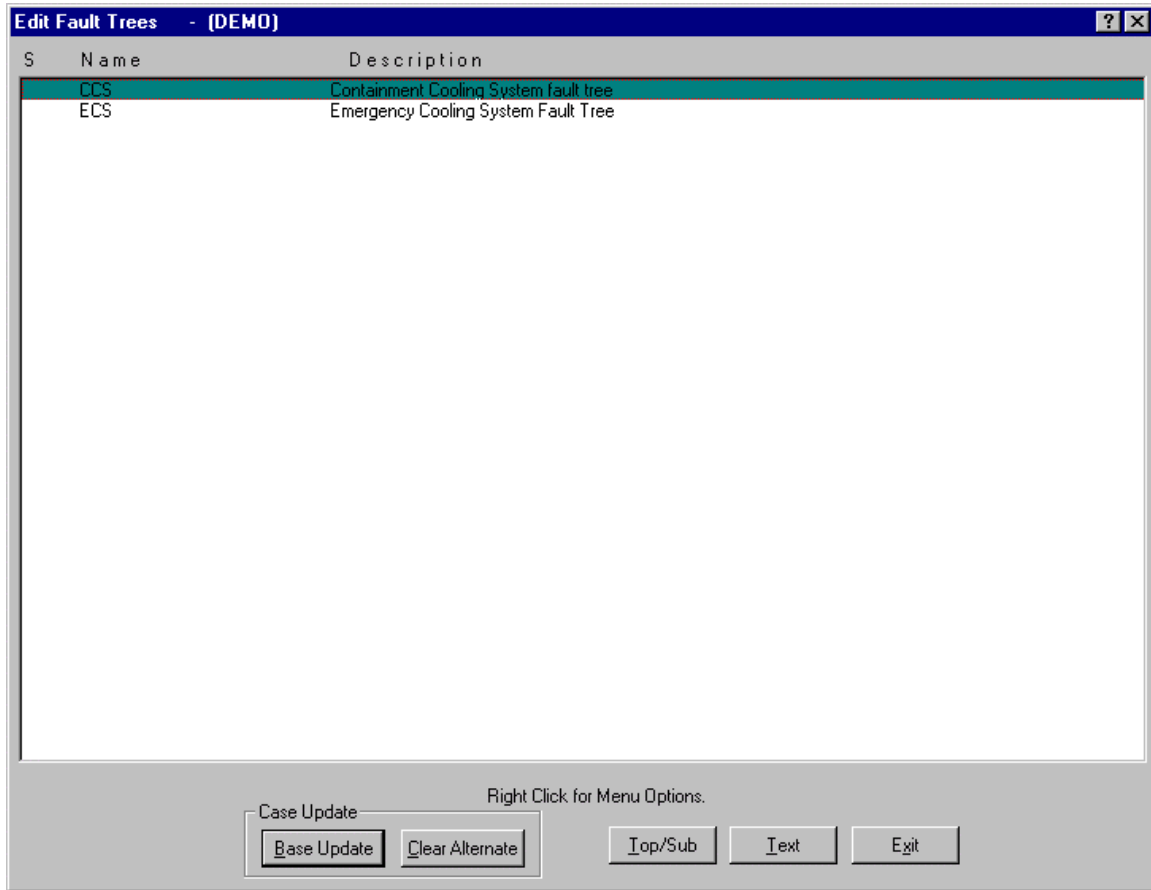
20.3 System fault tree results

- ◆ Prerequisites for system results base case update
 - ◇ Generate appropriate data changes for the analysis.
 - ◇ Analyze (i.e., generate cut sets) the system fault trees at a specified truncation level.
 - ◇ Review resulting cut sets for correctness.
 - ◇ Apply recovery rules to the system cut sets if required.
 - ◇ Perform uncertainty analysis if needed.

We are now ready to perform a base case update.

20.4 Menus and options for fault tree base case update

- Select the **Modify** **Fault Trees** menu.



- Mark the fault trees.
- Choose the **Base Update** button.

(The **Clear Alternate** button removes the results stored in the current (alternate) case.)

21. USING DATABASE FILES

Section 21 describes ways to transfer **event tree**, **fault tree** and **basic event** information from one project database to either a newly created project database or an existing project database.

- ◆ Give examples of the information stored in event tree, fault tree, and basic event MAR-D files.
- ◆ Describe the steps required to extract event tree, fault tree, and basic event files.
- ◆ Discuss how event tree, fault tree, and basic event information can be transferred from one SAPHIRE project to another.

21.1 Event Tree Files

- ◆ The event tree files created in SAPHIRE have the suffix of *.ET*.
 - ▶ These files store information about the event trees including logic, rules, and attributes.
 - ▶ The *.ETG file is created when the event tree is built and the logic is saved.
 - ▶ All other *.ET* files are created only by using the MAR-D **Extract** feature.
- ◆ SAPHIRE allows information pertaining to the event trees to be extracted from one project and **copied** to another SAPHIRE project.
- ◆ The MAR-D module in SAPHIRE allows the user to extract event tree information to be edited using a text editor.
- ◆ MAR-D also allows the user to **load** extracted files from another project into the current project.

MAR-D Load and Extract Menus



The MAR-D menus are provided in the **Utility Load and Extract** menu.

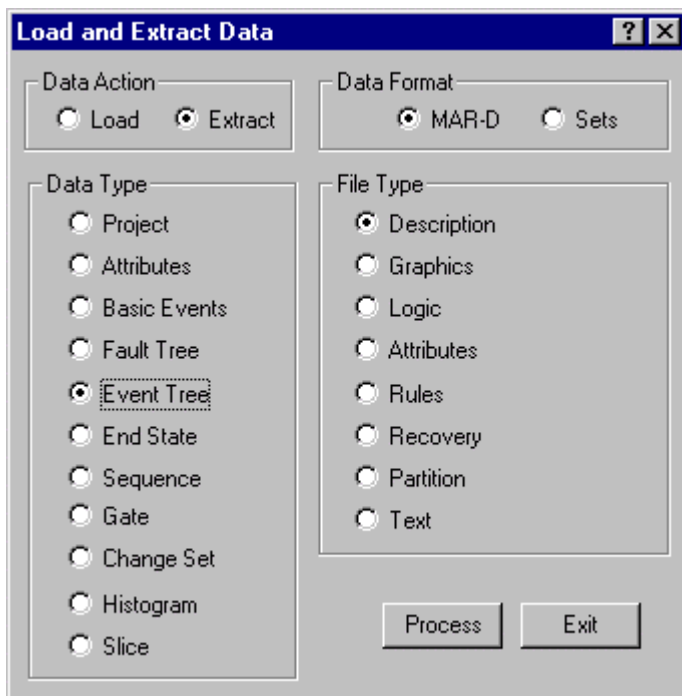
Extract Data

This option allows you to extract MAR-D files from the database into a text file.

Load Data

This option allows you to load MAR-D files that are contained in the project's subdirectory.

Load and Extract Event Tree Data



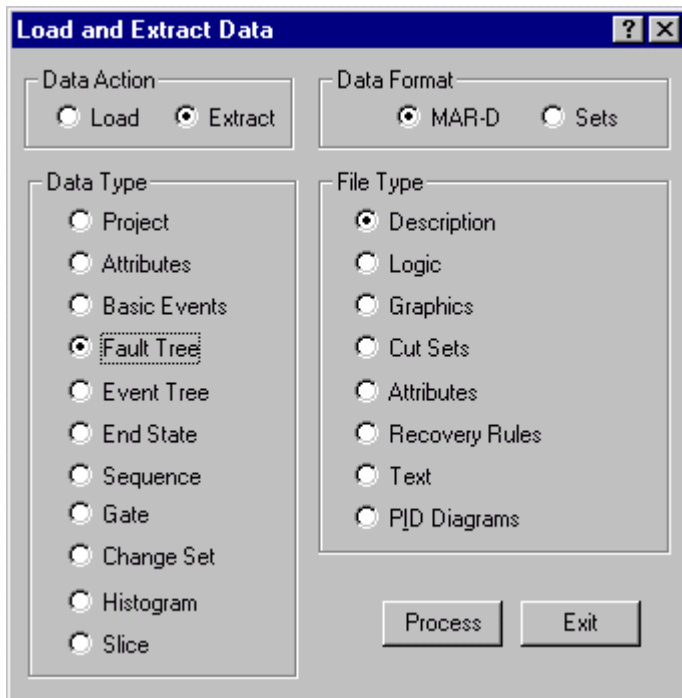
From the Data Action section, choose either the **Load** or **Extract** radio button.

- From the Data Format section, choose either the MAR-D or Sets radio button.
- Then choose the desired data type from the Data Type section.
 - The event tree information MAR-D format is selected in the figure shown above. Any one of the listed MAR-D file types can be accessed by selecting the appropriate radio button.
 - Choose the **Process** button.
 - You can mark individual event trees, a range of event trees, or all of the event trees.
 - Choose the **Extract/Load** button
 - When extracting, you will be prompted to accept or change the MAR-D file name. The default name is usually the project name and the MAR-D file 3-character extension (e.g., DEMO.ETD).
 - When loading, the files in the project directory that have the extension *.ET* will be listed on the dialog. Mark the file (or files) to load.

21.2 Fault Tree Files

- ◆ The fault tree files created in SAPHIRE have the suffix of *.FT* and *.DLS*.
 - ▶ The files store information about the fault trees, including logic, rules, and attributes.
 - ▶ The *.DLS files are created when the fault tree is built and the logic is saved.
 - ▶ All other *.FT* files are created only using the MAR-D **Extract** feature.
- ◆ SAPHIRE allows information pertaining to the fault trees to be extracted from one project and **copied** to another SAPHIRE project.
- ◆ The MAR-D module in SAPHIRE allows the user to extract fault tree information to be edited using a text editor.
- ◆ MAR-D also allows the user to **load** extracted files from another project into the current project.

Load and Extract Fault Tree Data

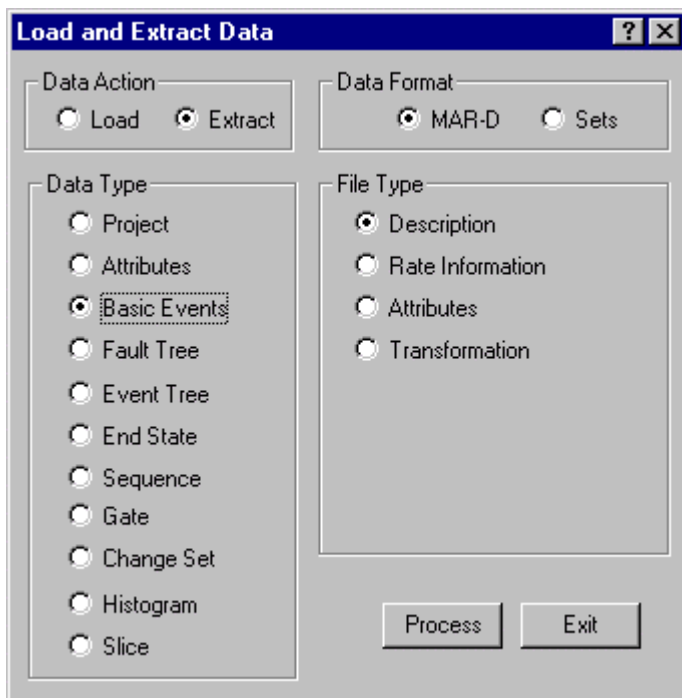


- From the Data Action section, choose either the **Load** or **Extract** radio button.
- From the Data Format section, choose either the MAR-D or Sets radio button.
- Then choose the desired data type from the Data Type section.
 - The fault tree information MAR-D file is selected in the figure shown above. Any one of the listed MAR-D file types can be accessed by selecting the appropriate radio button.
 - Choose the **Process** button.
 - You can mark individual fault trees, a range of fault trees, or all of the fault trees.
 - Choose the **Extract/Load** button.
 - When extracting, you will be prompted to accept or change the MAR-D file name. The default name is usually the project name and the MAR-D file 3-character extension (e.g., DEMO.FTD).
 - When loading, the files in the project directory that have the extension *.FT* and *.DLS will be listed on the dialog. Mark the file (or files) to load.

21.3 Basic Event Files

- ◆ The basic event files created in SAPHIRE have the suffix of *.BE*.
 - ▶ These files store information about the basic events, including probability information, attributes, and descriptions.
 - ▶ The *.BE* files are created only by using the MAR-D **Extract** feature.
- ◆ SAPHIRE allows information pertaining to the basic events to be extracted from one project and **copied** to another SAPHIRE project.
- ◆ The MAR-D module in SAPHIRE allows the user to extract basic event information to be edited using a text editor.
- ◆ MAR-D also allows the user to **load** extracted files from another project to the current project.

Load and Extract Basic Event Data



- From the Data Action section, choose either the **Load** or **Extract** radio button.
- From the Data Format section, choose either the MAR-D or Sets radio button.

- Then choose the desired data type from the Data Type section.
- The basic event information MAR-D file is selected in the figure shown above. Any one of the listed MAR-D file types can be accessed by selecting the appropriate radio button.
- Choose the **Process** button.
- You can mark individual basic events, a range of basic events, or all of the basic events.
- Choose the **Extract/Load** button.
- When extracting, you will be prompted to accept or change the MAR-D file name. The default name is usually the project name and the MAR-D file 3-character extension (e.g., DEMO.BED).
- When loading, the files in the project directory that have the extension *.BE* will be listed on the dialog. Mark the file (or files) to load.

21.4 Moving Database Files

Database information from one SAPHIRE project can be moved into another SAPHIRE project. By moving information (i.e., database files) from one database project another database project you may, reduce the time required to duplicate this information in the new SAPHIRE project.

- ◆ Copying extracted MAR-D files from one SAPHIRE project to another SAPHIRE project:

- ① Go to the SAPHIRE project directory that contains the files to be copied.

This directory may be **C:\SAF60\DEMO** (or what ever your project subdirectory is named).

- ② Highlight all of the database files in the project subdirectory. Hold down the <Ctrl> key and drag the files to the destination project directory.

This will copy those files highlighted from the DEMO project into the specified SAPHIRE project.

- ◆ The files just copied may need to be loaded into the new SAPHIRE project (if they were MAR-D files).

- ① In SAPHIRE select the project directory that the files were copied to (using the **File → Open Project** menu).

- ② Load the MAR-D files into the project from the **Utilities** **Load and Extract** menu.
- ③ Recover the database from the **Utility** **Recover Data Base** menu.
- ④ Generate event data from the **Generate** menu.